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VOL. XXIII.

motors in the ordinary sense, as they develop no work by themselves. They have only the property of storing a small amount of motive force developed by muscular action, and of releasing it under conditions entirely different from those attending its accumulation. Thus by turning a crank slowly with considerable effort for a short time, we store up a certain amount of work which may be made to run a light machine at high speed against a light resistance, through a comparatively long time. Unfortunately only a small part of the work is utilized, and the labor of winding up the machine is far from being compensated by the useful effect obtained. The amount of work that can be accumulated in a steel spring without passing the limit of elasticity is, of course, limited. It will vary naturally with the quality and size of the spring. Experience shows that when employing the best steel known, converted to the form of a clock spring (which is the most favorable for such a service), the amount of work stored will not exceed 40 kilogrammeters for each kilogram of metal.

In practice the loss from friction and deformation of the spring is about 80 per cent. It is true that the majority of the steam engines afford no better return of the total work stored in the fuel, but these latter consume coal only, while the spring motors run at an expense of muscular force, which is the most expensive and the most precious of all sources of mechanical work.

M. Fontaine declared that the springs could be profitably replaced by a weight which would restore a large proportion of the labor expended upon raising it. A weight of 100 kilograms raised three meters would afford a very economical accumulator, and one less liable to deterioration.

From electric engines we can no longer hope for economical results. An electric motor is nothing more than a reversible magneto-electric machine. The latter will receive a current of electricity, and under its influence will take on a rotatory movement. But from whence comes the current? From a galvanic battery or from another magneto-electric machine? In the latter case it is only a transmission of power which is effected by electricity, and it is not a solution of the problem of domestic motors. If the power is derived from a battery, then the battery is consuming zinc and acids, of which the price per unit of work is far above that of coal or gas, or any of the so-called combustibles.

It suffices to know that a magneto-electric machine, worked by a single man, develops as much electricity as a battery of six Bunsen cups, each eight inches high, and freshly charged, in order to conclude that it would be necessary to employ more than six cups to drive a machine of one-man power.

Engines driven by water seem much more attractive. They require no fuel nor any special agent to operate them. But while the fear of fire is not attendant upon their use, the accidents arising from freezing have their inconveniences.

But here again it is the question of economy, which is of the first importance; and as the cost of water varies much in different places, M. Fontaine bases his calculations upon the conditions which obtain in Paris. This city possesses, on the one hand, a good supply of water, and on the other, supports a multitude of industries based upon indoor labor at home.

The pressure of water in Paris is equal to a head of 40 meters in the neighborhood of the Seine, and only 10 meters in the higher portions. In more than half the dwellings the water cannot be delivered in the upper stories.

The charge for water from the Dhuys or the Seine is 0.f33 (6$\frac{1}{4}$ cents) per cubic meter, if the quantity used is not more than 5 cubic meters per day. When from 5 to 10 meters are used per day the price is 0.f27, and for 10 to 20 cubic meters it is only 0.f22. The water of the Ourcq costs one-half less, but the pressure is too slight to be serviceable for motive power.

Assuming a pressure corresponding to a head of 20 meters and an efficiency of sixty per cent. for the motor, the quantity of water necessary to afford a work equal to six kilogrammeters per second will be 1,800 liters per hour and 18 cubic meters in 10 hours. The daily expense would be four francs.

There are many cities, however, in which the pressure is high and the price moderate. In Lille, for instance, the head is 30 meters and the price only

seven centimes ($1\frac{1}{3}$ cents) per cubic meter. In Switzerland most of the cities are provided with a water supply.

After enumerating and describing the various forms of hydraulic motors, M. Fontaine passed to the consideration of small steam engines. There are in reality but few domestic motors of this class, and M. Fontaine has best explained the reason for this fact by re-counting the revolutions through which a little engine of his own invention was made to pass. The authorities would not permit his microscopic boiler to be used without the usual safety apparatus; valves, gauge-cocks, water level indicators and all, and this was notwithstanding the fact that the boiler could not be fed while working, and the limit of pressure was provided for.

The necessity of obeying the ordinance of 1865 prevented this engine from giving good results, because the safety apparatus, reduced to the scale of the boiler, worked so badly.

We come finally to the gas engines. These are the most numerous and certainly best motors for light work, provided a supply of gas is available.

To define a gas motor it will suffice to quote the words of M. Armengaud Jr., in a lecture on the subject before the conference at the Trocadero in August 1878 (see VAN NOSTRAND'S MAGAZINE, Vol. 20, page 148).

"A gas engine possesses the essential organs of the steam engine; the cylinder which receives the gaseous fluid; the piston, which, by aid of rod and crank, transmits the pressure to the shaft; the fly-wheel, which regulates the motion, and the pulleys and belts by which the power is conveyed to the machines to be driven.

"The gaseous fluid is a mixture of gas and air, in such proportions as is most susceptible to explosion when in the neighborhood of an ignited body. The mixture is exploded by a little flame, and the products of the combustion suddenly dilated by the heat, urge the piston, and thus develop the motive power."

The Hugon engine was one of the first to prove capable of application to industrial purposes. It utilizes the expansion directly. It is a double acting engine, and the piston at each stroke admits the explosive mixture (which is exploded at the half-stroke) on one side, and expels the products of the previous explosion on the other. The mixture is exploded by a gas flame. The engine is horizontal.

The Otto and Langen engine is vertical, and employs the force of explosion indirectly. The piston is first driven upward like a projectile by the direct force of the explosion. The gases expand, following the piston; and even after they have become reduced to the atmospheric pressure, the piston continues on its upward stroke by reason of its acquired momentum. It stops when the atmospheric pressure has absorbed the accumulated work. The gas under the piston has become rarefied and cooled; the watery vapor is consequently condensed and the piston descends, urged by atmospheric pressure aided by its own weight.

This mode of action which has proved very economical when compared with other methods, has the unfortunate peculiarity of making an insupportable noise, and which has, in great measure, prevented its extended use.

The Bischopp engine belongs also to the class which utilizes the explosion during the ascent of the piston. The cylinder is vertical, and the piston communicates its motion to the shaft by means of a connecting rod. These machines have been constructed for light work, and especially to drive sewing machines. They are run in Paris at an expense of 10 centimes per hour for $\frac{1}{15}$ of a horse power, or of 25 centimes for $\frac{1}{2}$ a horse power.

In 1877 a Bischopp motor attached to an electro-plating establishment ran without any attention 47 days and 47 nights; that is, until it completed the work. No other known motor could have done this.

"Our conclusion," says M. Fontaine, "is plainly derived from the results of such examinations as these.

"In the present state of our knowledge, we would advise buyers to get the small Bischopp gas engine, and would advise inventors to seek to devise a small steam engine to be run by burning coal, and furnished with an automatic regulator for the combustion."

BALANCING LOCOMOTIVE ENGINES.

By C. A. SMITH, B. S., Fort Wayne, Ind.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THERE is comparatively little information to be found in print upon the subject of balancing engines, and in works where the subject has been touched upon at all, the information given is so brief and condensed that little satisfaction is obtained by mechanics who may be seeking for knowledge in this direction; and as the writer has been frequently consulted, he hopes to be able to give such information in the following pages as may be desired by those interested.

The importance of balancing locomotive engines will be questioned by no one who has had sufficient experience in machinery, if not a technical knowledge of the same. It prevents unnecessary "wear and tear" of the machinery as well as dangerous oscillations which would have a tendency to cause the engine to jump the track. As the forces which cause these oscillations increase as the *square* of the angular velocity of the wheels, other things being equal, it becomes very important to take particular pains in balancing high speed or passenger engines; this not only to secure safety to life and property, but also to enable the engine to make the best time possible. It is not safe to run an imperfectly balanced engine beyond a certain speed.

To have any machine, or part of a machine revolving or oscillating about an axis, perfectly balanced, the principles of mechanics require an equilibrium of both the *centrifugal forces* and the *centrifugal couples.** This, then, furnishes us the basis for determining the necessary formulæ.

The weight of the reciprocating parts (piston, crosshead, etc.), should not be counterbalanced on the main drivers alone, but this weight should be distributed equally among all the drivers. The reason of this is readily understood, as the full force of this weight acts upon the wheels only when the crank is on its "centers." When the crank is vertically over, or under the axle, it has little or no influence in disturbing the equilibrium of the wheels as far as centrifugal force is concerned. The result of this will be that when the wheels are perfectly balanced on the "centers," as they should be, they will be overbalanced when the crank is at right angles to the center line of the cylinder. As this cannot be avoided, the balancing of the reciprocating parts should be distributed equally among all the drivers, thus distributing the over-balance among all the wheels. The most important point is to have the wheels well balanced *on the centers*, as it is the *horizontal thrust* which has a tendency to cause the engine to sway sideways, pressing the wheels against the rail, and thus making them liable to climb the rail which would result in the engine leaving the track. As far as the disturbing force on the "centers" is concerned, it will practically remain the same, if we suppose the weight of the reciprocating parts to be equally divided among the drivers and concentrated at the crank pins. This will facilitate the application of mathematics to the case.

Let us adopt the following nomenclature for the sequel:

W = weight of reciprocating parts—piston, piston rod, crosshead and main connecting rod.

P = that part of the parallel rod's (or rods') weight which is supported by the crank pin of the wheel under consideration.

w = combined weight of the counterpoise and crank of one wheel.

r = radius vector of w—*i. e.* the distance from center of axle to center of gravity of counterpoise and crank.

c = length of crank.

a = distance between middle of main rod connections, measured parallel to the axle, as shown in Fig. 2 = distance between centers of cylinders.

b = distance between center of gravity of counterpoise = distance between middle of "wheel centers"—Fig. 2.

* Rankine's Machinery and Millwork, pages 365–8.

d=distance between middle of parallel rod connections.

φ=angular velocity of wheels.

g=force of gravity.

θ=angle, which the line drawn from the center of the wheel through the center of gravity of the counterpoise and cranks makes with the crank line. See Fig. 1.

n=number of driving wheels on one side of locomotive.

In Fig. 1 is represented the general arrangement of the principal parts of a pair of wheels. Suppose planes A and B to pass through the axis $\overline{OQ}$ and the cranks $\overline{OA}$ and $\overline{QB}$ respectively—being at right angles to each other.

Now, the forces acting upon a wheel,

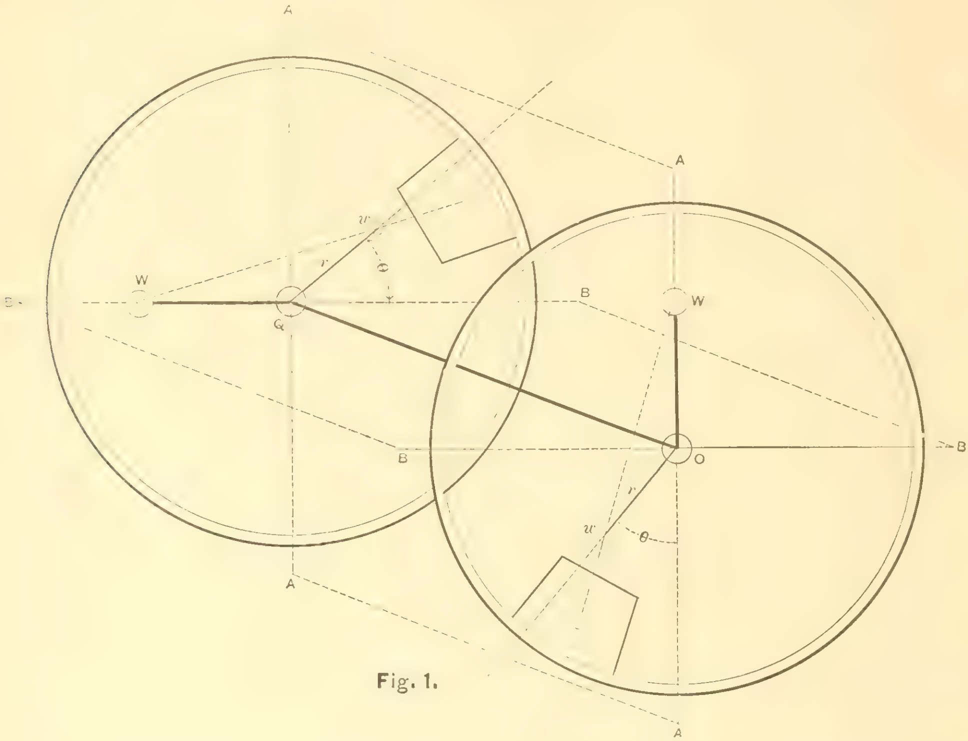


Fig. 1.

in a radial direction, at the instant the crank passes its center, may be divided into three distinct parts, viz.: the centrifugal force of the crank and counterpoise, acting at their joint center of gravity; the centrifugal force of part of the parallel rod acting on the crank pin, and the force due to the momentum of the reciprocating parts which may be considered equivalent, in effect, to the centrifugal force of an equal weight concentrated at the crank pin.

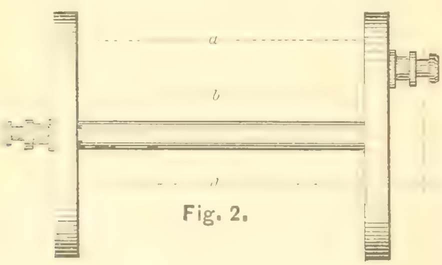


Fig. 2.

Resolving these forces into the planes A and B, Fig. 1—distributing the weight W as previously stated—we have

$$\frac{P\varphi^2 r}{g},\ \frac{W\varphi^2 c}{ng}\ \text{and}\ \frac{w\,\varphi^2 r\sin.\theta}{g}$$

as the forces acting in the plane B, towards the left. The opposing force in this plane is

$$\frac{w\,\varphi^2 r\cos.\theta}{g}$$

Equal forces act in the plane A. Now,

in order to have these forces balance each other we must have, first

$$\frac{W\varphi^2 c}{ng}+\frac{P\varphi^2 c}{g}+\frac{w\varphi^2 r\sin.\theta}{g}=\frac{w\varphi^2 r\cos.\theta}{g}$$

or.

$$\cos.\theta-\sin.\theta=\frac{c}{wr}\left(\frac{W}{n}+P\right) \quad . \quad (1)$$

Second, taking the origin at the middle of axle for centrifugal moments, we must have

$$\frac{W\varphi^2 ca}{2ng}+\frac{P\varphi^2 cd}{2g}=\frac{w\varphi^2 rb\sin.\theta}{2g}+\frac{w\varphi^2 rb\cos.\theta}{2g},$$

or

$$\cos.\theta+\sin.\theta=\frac{C}{wrb}\left(\frac{Wa}{n}+Pd\right) \quad . \quad (2.)$$

Combining equations (1) and (2) we have

$$\tan.\theta=\frac{\frac{W}{n}(a-b)+P(d-b)}{\frac{W}{n}(a+b)+P(d+b)} \quad . \quad (3)$$

From this equation can be determined the *angular position* of the counterpoise. Also by a proper combination of equations (1) and (2) we obtain

$$w=\frac{c}{r}\sqrt{\frac{\left(a\frac{W}{n}+Pd\right)^2+b^2\left(\frac{W}{n}+P\right)^2}{2b^2}}. \quad (4)$$

which determines the *weight* of the counterpoise and crank. These equations are applicable to all cases in locomotive practice.

It is a general practice to place the counterpoise directly opposite the crank. If this is correct then the first member of equation (3) should be zero. This is only possible when $a=b=d$ or when

$$a=\frac{nP}{W}(b-d)+b. \quad . \quad . \quad . \quad (5)$$

But a, b and d can never be made equal to each other in practice and to have the relation of these quantities as expressed in equation (5) would require the engine to be "*inside connected*" as an examination of this equation will show. If these quantities would ever have this relation, it would only be by chance and hence it would possibly be correct, once in a thousand cases, to place the counterpoises *opposite the cranks, on inside connected engines*, but on *outside connected engines—never*.

Having now found the key for balancing locomotive engines, let us next consider

THE PRACTICAL OPERATIONS

of locating the counterpoises and adjusting them to the proper weight. This naturally divides itself into two parts:

I. To separately locate the counterpoises on the wheels, and to adjust their weights according to the formulæ already deduced.

II. To make a final adjustment by means of dynamical tests.

Part I.

Under this division of the subject we have two cases; first, solid or fixed counterpoises cast solidly into the wheels, and second, removable counterpoises.

Case 1.—The adjustment of solid counterpoises must be made before the

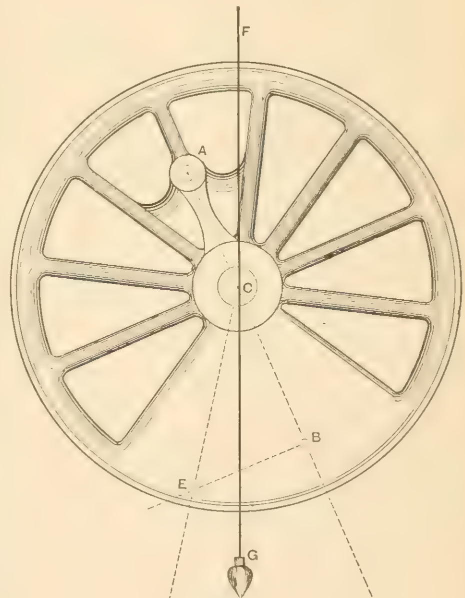


Fig. 3.

wheels are pressed upon the axle, otherwise the angular position of the counterpoise would be indeterminate.

To commence, then, locate the point B, Fig. 3, upon the crank line $\overline{ACB}$, at some convenient place. Next lay off, from B and perpendicular to $\overline{CB}$, a distance

$$\overline{BE}=CB\ tan.\theta. \quad . \quad . \quad . \quad (6)$$

The value of *tan.θ* is obtained from equation (3). Having thus located the point E, fix its position with a prick punch. This gives the proper angular position of the counterpoise, viz.: BCE$=\theta$. The *sign* of *tan.θ*, as found from equation (3) will determine whether the point E should be laid off on the left or right side of $\overline{CB}$. That is, when *tan.θ* is positive then the cranks and counterpoises should have the relation shown in Fig. 1, but if *tan.θ* is negative then E should be laid off on the opposite side of the crank line CB. This, however, will only be the case with inside connected engines.

By a careful inspection of equation (3) and Fig. 1 we deduce the following rule:

Place the counterpoise (or the line $\overline{EC}$, Fig. 3), on that side of the crank line $\overline{CB}$ on which the crank of the opposite

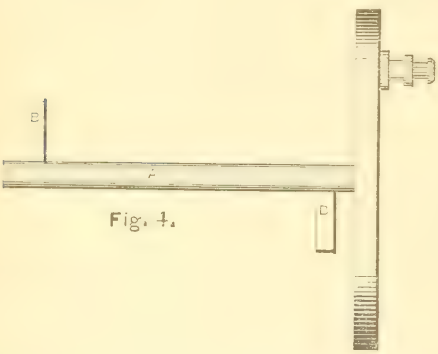


Fig. 4.

wheel is situated, for *outside connected engines*, and on the opposite side for *inside connected engines.*

For example, to locate the counterpoise on the wheel O, Fig. 1, we see that the crank $\overline{QW}$, on the opposite wheel, projects to the *left* of the crank line OA (or the plane A), hence the counterpoise (or the point E, Fig. 3), should be placed on the *left* side of the crank line OA if it is for an *outside connected engine*, but if it is for an *inside connected engine* the counterpoise should be placed on the *right hand side* of the crank line OA.

Having located the point E, Fig. 3, as explained, fix the wheel temporarily upon a shaft, A, Fig. 4, and place it upon leveled straight edges, B, as shown. Now let the wheel come to rest in its natural position, as in Fig. 3. Hold a plumb line FG over the center, C, of the wheel. If the plumb line does not pass directly over the point E, then the counterpoise is either too light or too heavy. If it should take the position shown in Fig. 3 and the counterpoise is too heavy, then some metal must be *removed* on the *right* of the plumb line; but if it is too light then some metal must be *added* on the *left* of the plumb line in order to bring it over the point E. To ascertain whether the counterpoise is too light or too heavy, turn the wheel to the position shown in Fig. 5, bringing the line $\overline{CE}$ to a horizontal or level position. Hold the wheel in this position by means of a spring balance or scales applied at the point E. Let w_1 represent the weight which should be indicated by the scales when the counterpoise is of the proper weight.

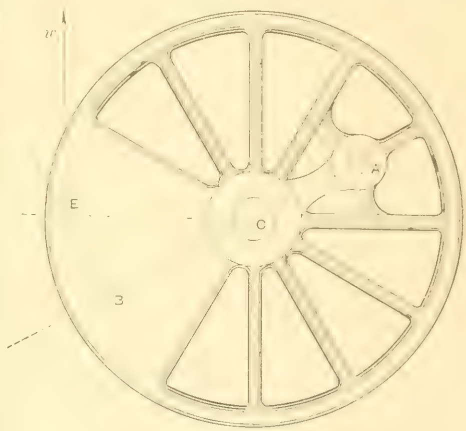


Fig. 5.

The value of w_1 may be obtained from the equation

$$w_1 = \frac{c}{\overline{CE}^*}\sqrt{\frac{\left(\frac{aW}{n}+Pd\right)^2+b^2\left(\frac{W}{n}+P\right)^2}{2b^2}} \quad (7)$$

If the scales indicate more than the weight w_1, as computed from this equation, then the counterpoise is too heavy, and *vice versa*. When the counterpoise is so adjusted that the weight indicated on the scales is equal to w_1, as computed from equation (7), and the plumb line, Fig. 3, passes through the point E, then it is adjusted as it should be. Care must be taken not to locate the point E on the wrong side of the crank line. To avoid this mistake it must be first

* The distance $\overline{CE}$ in Figs. 5 and 3.

decided upon, and clearly borne in mind, what situation the wheels will have when pressed upon the axle. Of course this must be done before the rule of page 12 can be applied. If the crank pin is not on the wheel when the adjustment is made, then its weight should be added to $\frac{W}{n}$ in the equation before the calculations are made.

Case 2.—In case of removable counterpoises we may temporarily bolt them in their proper places, and then proceed as in case 1, if the adjustment is made before the wheels are pressed upon the axle, but if the wheels have been pressed upon the axle previous to the adjustment of the counterpoises, we must proceed as follows:—

After the counterpoises have been fitted to their places between the spokes of the wheel, remove them and bolt each pair together as seen in Fig. 6—No 1. Now locate the center of gravity of each pair on the outside. This may be conveniently done by suspending them with a grip-hook, as shown, and suspending a plumb line from the point of the hook. Mark the position of the plumb line, as $\overline{AB}$, Fig. 6, No. 2; then suspend the

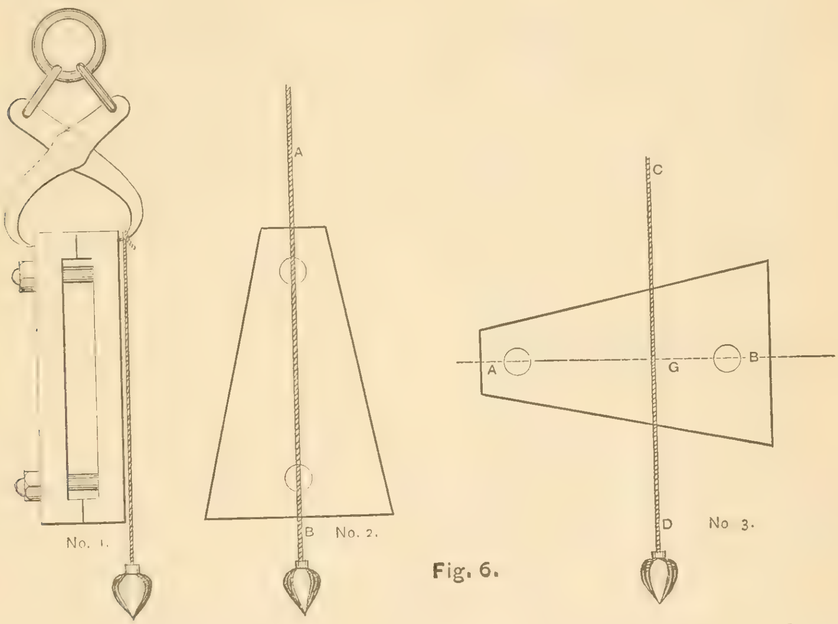


Fig. 6.

counterpoise in another position, and mark the plumb line as at $\overline{CD}$—No. 3. The intersection, G, of these two lines will be the center of gravity sought. Now weigh each pair separately, and mark the weight upon it. Next place the wheels upon leveled straight edges, before the counterpoises have been put in place, and turn them so that the crank line of one wheel shall be in a vertical position, then the other will be horizontal, as in Fig. 1. Hold the wheels in this position with the scales applied to the crank pin of the horizontal crank. The weight indicated on the scales in this position will be a weight which, when applied at the crank, will have the same centrifugal force as the crank itself. It may, therefore, be substituted for the latter. Let us denote this weight by *m*. Now fasten the counterpoises in their respective places between the spokes, as in Fig. 7. Let G_1 be the center of gravity of the first pair, G_2 that of the second, G_3 of the third, etc. Also let w_1, w_2, w_3, etc., be their respective weights. Mark the line $\overline{CE}$ upon the wheel, the angle $\overline{BCE}$ being determined as in case 1. Now find the center of gravity of the counterpoise and crank combined as follows:—

Join G_1 and G_2 and lay off from G_1 the distance

$$\overline{G_1F} = \frac{w_2 \times \overline{G_1G_2}}{w_1 + w_2} \quad . \quad . \quad . \quad (8)$$

Next lay off on the line FG_3

$$\overline{FH} = \frac{w_3 \times \overline{FG_3}}{w_1 + w_2 + w_3} \quad . \quad . \quad . \quad (9)$$

and finally,

$$\overline{HG} = \frac{m \times \overline{HA}}{w_1 + w_2 + w_3 + m} \quad . \quad (10)$$

The point, G, thus found is the center of gravity sought—of the counterpoise and crank. The weights, w_1, w_2 and w_3, should be so adjusted that the point G will fall upon the line $\overline{CE}$ and the *sum* of the weights w_1, w_2, w_3 and m equal the weight w as computed from equation (4), in which we must substitute, for r, the length CG. Fig. 7.

This method is not as accurate as that of Case 1, and it is at the same time a great deal more tedious, but it is the only way we can make the adjustment after the wheels are on the axle.

In making patterns for wheels the

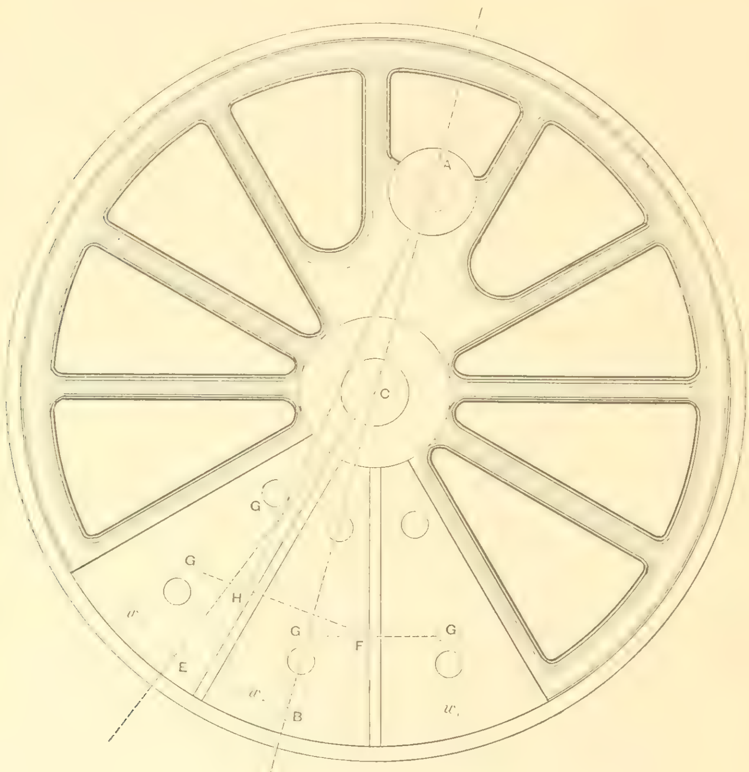


Fig. 7.

weight and position of the counterpoises may be approximately determined in the same manner as herein set forth, by multiplying the results obtained from the equations, before using, by 0.092 if pine wood is used.

Of course it will be unnecessary to remark that the wheels can be given a symmetrical appearance, although the center of gravity of the counterpoises is set to one side of the crank line. This can be done by simply making the counterpoises heavier on one side of the crank line than the other.

Part II

FINAL ADJUSTMENT.

Although the adjustment of Part I. will give a better result than is obtained by the ordinary practice it will not be perfect, owing to the impossibility of taking into account various slight causes

which have an influence in modifying the action of the machinery. The adjustment may, however, be much improved by making what may be termed *dynamical tests*, with which we may proceed as follows:—

After the counterpoises are adjusted according to Part I. and the engine is ready to "fire up," it should be suspended by four points of its frame from some rigid frame-work, sufficiently high above the track so it may swing freely. Fix a pencil on a spring and fasten the latter to the engine at some convenient point. Next take a board, upon which has been mounted a piece of paper, and fasten it to some stationary object immediately beneath the pencil point, in a horizontal position. Fasten also a piece of chalk, by means of a spring, at some convenient point near one of the driving wheels. Connect the pencil and chalk in such a manner that the former

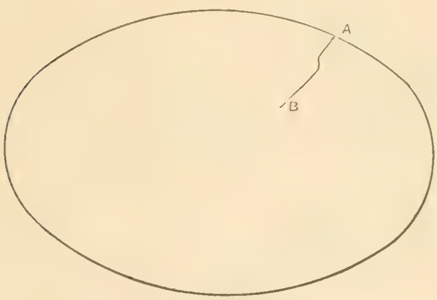


Fig. 8.

may be drawn to one side at the same instant that the latter is pulled against the wheel. This may be done by means of a string. Everything being thus prepared, turn on the steam and set the wheels in motion—the driving boxes having been previously blocked up. As the machinery is thus in motion, the engine will swing in an orbit, the form of which is traced by the pencil point when brought in contact with the paper. This orbit will generally be elliptical in form, as shown in Fig. 8. At any time while the machinery is in motion, suddenly pull the string connected with the pencil and chalk, so as to make, simultaneously, a mark on the wheel and across the orbit as AB. The point A will, of course, indicate the position of the pencil point at the instant the string was pulled. The position of the wheels at the same instant is determined by simply turning them, until the chalk-mark made stands opposite the piece of chalk. Having thus determined the relative positions of the pencil and wheels at the same instant, we can at once see whether the counterpoises are still too heavy, and more metal may then be removed, or *vice versa*.

If an engine could be perfectly balanced the orbit described by the pencil point would be reduced to a point; that is, the engine would remain perfectly at rest, however rapid the motion of the machinery might be. But this condition of things can never be realized in practice. We can only make *perfection* our objective point towards which we will work, and the man who can approximate nearest to it is the "biggest success." Prof. Rankine* seems to think that the approximation may be so near to perfection that the diameter of the pencil's orbit be reduced to one-sixteenth of an inch. This would, indeed, be a very satisfactory result, and beyond our expectation.

Chinese Steel.—A considerable steel-making industry exists in the present day in China, on the Upper Yangtze, whence the steel is sent to Tient-sin for shipment and distribution. It fetches much higher prices than the Swedish steel imported into the country. The Chinese metallurgists recognize three kinds of steel—namely, that which is produced by adding unwrought to wrought iron while the mass is subject to the action of fire; pure iron many times subjected to fire; and native steel, which is produced in the south-west. The different names for steel are twan kang, or ball steel, from its rounded form; kwan kang, or sprinkled steel; wei tee, or false steel. The Chinese, apparently have known how to manufacture steel from the very earliest ages, and in the time of the Hau dynasty iron-masters were appointed in several districts of the old Leangchou to superintend the ironworks.—*Iron.*

* Rankine's Steam Engine, page 531.

DETERMINATION OF THE THICKNESS AND FORM OF THE ARCHES OF STONE BRIDGES.

By G. TOLKMITT.

(Zeitschrift des Architekten-und Innegieur-Vereins zu Hannover.)
Translated for Institution of Civil Engineers.

The thickness necessary for the arch of a stone bridge depends on the strength of the material of which the arch is built, the load it has to bear, and the form and dimensions adopted for the archring. All empirical formulæ, used for determining the depth at the crown, which do not contain these three factors can only be regarded as giving adequate approximation when applied within narrow limits. If the span of the arch be small, and the backing above it of little depth, it is necessary besides to take account of a partial distribution of the live load. It may generally be said, that the thickness required will be least when the form chosen for the arch is such as to make the line of pressure which corresponds to full loading coincide with the mean line of the archring. In a former paper, published in the "Zeitschrift für Bauwesen" of 1876, the author has gone fully into this question; and the results then obtained have been collected and reproduced in a small table. The chief object of the present paper is, however, to establish a formula which, while taking due account of the three factors, gives also an easy means of determining the thickness at the crown of such arches. The formula is not strictly accurate, but numerous applications which have been made of it have proved that the approximation, even in extreme cases, is very great.

The author examines two distinct cases: 1st. The evenly distributed live load, covering the entire length of the span. 2nd. The live load extending only from one of the abutments to the center of the arch. The latter case leads generally to greater thicknesses than the first, but still it is always advisable to try both hypotheses. If c be the thickness at crown, it can be expressed in the first case by

$$c=\frac{.15\times\frac{w^2}{f}}{q-.15\,\frac{w}{f}}\left(e+p+\frac{f}{10}\right).$$

e, depth at crown of the surface, representing the permanent load on the arch. It is comprised between the extrados and a horizontal line above it.

p, depth of horizontal strip, representing the live load.

w and f, span and rise of the intrados of the arch.

q, greatest pressure admissible on the stone.

The formula is independent of the choice of unit, which may be at pleasure the foot, the yard or the meter. Although q is equivalent to a weight, it is not to be expressed by a number of units of weight, but by the volume of stone of a like weight. Thus, supposing the stone to be able to bear safely 80 tons per square meter, and to weigh 2 tons per cubic meter, the numerical value of q to be introduced into the formula will be $\frac{80}{2}=$ 40 cubic meters.

In the second case, that of partial distribution of the live load, the expression of c depends on the nature of the assumption which is made with regard to the springings. When they are assumed as rigidly fixed, the value of c will be smaller than when they are supposed to admit of slight angular displacements. It is, therefore, judicious to adopt the second hypothesis, although probably farther from the truth than the first. The equation becomes in this case,

$$c=.625\times p\,\frac{f}{c+e+\frac{p}{2}+\frac{f}{10}}\times\frac{2w-f}{2w}.$$

The symbols have the same signification as before. The thickness at the crown being computed, there remains to draw the arch in its right form. This is done by means of the table already cited. The operation is extremely simple, reducing itself to the multiplication by numerical co-efficients of a series of figures contained in the table.

COLOR BLINDNESS IN RAILWAY EMPLOYEES.

Abstract of Report of Massachusetts Railroad Commissioners.

The Board gave early attention to this subject, witnessing an interesting examination of railroad employés, conducted by Dr. Jeffries, and listening to his explanation of his theories and methods. They also united with him in sending circulars of inquiry to various experts and officials in Europe. They have examined a large number of persons, chiefly employed by several railroad companies, using for tests, colored worsteds, as recommended by Professor Holmgren, and as practised by Dr. Jeffries. This examination was supplemented by experiments with colored flags and lanterns whenever any visual defect was found to exist. They have also sought, by reading and conversation and correspondence with persons practically interested in the matter, to obtain information on the subject.

Any one who engages in the study, will find himself anticipated in every direction by Dr. Jeffries, who has pursued it with unwearied industry, and to whom the community is deeply indebted for his labors. If he has exaggerated the importance of his subject, or the frequency and extent of the defect which he discusses, it is the natural and honest exaggeration of an enthusiast devoted to a specialty in science.

It has long been known that there is such a defect in vision as color-blindness. In rare cases it is total; more frequently it is partial. Various divisions have been made by different writers in describing this defect. Professor Holmgren's division is as follows: I. Total color-blindness. II. Partial, which he subdivides into: 1. Complete color-blindness, including red-blindness, green-blindness and violet-blindness. 2. Incomplete color-blindness, where the sense as to one or more colors is feeble. His divisions are cited, for he is often quoted; and it is necessary to remember that with him one subdivision of "partial color-blindness," is "complete color-blindness," as this phrase is likely to mislead. The different species of this defect, practically important in connection with railroads, are total color-blindness, which is very rare, red-blindness and green-blindness. The red-blind confound red with green, with gray or brown, and sometimes with black. The green-blind confound green with red, or with gray and brown. The inability to distinguish red and green, is not only the most marked species of color-blindness, but it is in practice the most important, as these colors have been very generally chosen to signify danger and safety on railroads, and universally to mark port and starboard on the sea.

Generally the defect exists from birth, being often hereditary. The learned Dr. Pliny Earle, who wrote a valuable article on this subject in 1845, knew seventeen persons of different generations in his own family, who were utterly unable to discriminate between red and green. Sometimes it is caused by sickness or injury; and frequently it results from the excessive use of liquor or tobacco. Often the defect is unsuspected for years. This happened in the case of the famous John Dalton, whose name has long been connected with this peculiarity of vision. It is the general belief in Rome that Garibaldi selected the red flannel, which increased the exposure of his soldiers to the marksmen of the enemy, in full belief that it was dark green, laying his hand on a scarlet piece of cloth instead of a green one, when choosing the material for their uniform. Even if the story is unfounded, it shows that the existence of total color-blindness is recognized and notorious, not only among men of science, but among all classes of people.

It need hardly be said that such a defect is a source of danger, while railroad trains are run by colored signals. It is true that the commissioners have not been able to find that any railroad accident has ever been clearly traced to this cause. Professor Holmgren indeed says that, in a certain trial, "testimony was adduced which had led me to suppose that color-blindness was one of the principal causes of the disaster." He

and other writers speak of it as a cause of accident in other countries, or in distant places. *The Scientific American*, in the number for July 9, 1853, refers to color-blindness as a possible cause of the terrible Norwalk accident of May 6, 1853, by which forty-six persons were killed. But no investigation on this point seems to have been made, and upon examination the facts do not appear to warrant any such conclusion. The same excellent journal had called attention to the subject in its number of May 28. The director of the Swedish State Railroads, C. O. Troilius, who has given especial attention to the subject, writes: "No accident traceable to color-blindness, as far as we know, has occurred on our lines." One of the railroad journals of this country, *The Railway Age*, in its investigation of the subject, has received answers from thirty-seven superintendents, and other managers of railroads, no one of whom had ever heard of an accident resulting from color-blindness. This, of course, does not prove that no such accident ever did occur.

The possibility of accident arising from this cause has been shown. And as to one employé, recently for the first time discovered to be color-blind, it appears that on former occasions he has led several engineers into errors, for which they have been reprimanded. No doubt now exists that he did this by displaying the wrong signals. Each of these errors might have resulted in disaster. The defect was unknown to the man himself, but was manifest at once on his being examined by the intelligent officer detailed by the superintendent of the road for that duty, and whose skill and thoroughness is elsewhere spoken of. It is hardly necessary to add that the person examined is now in a position where perception of color is not needed.

In *The Chicago Railway Review* for March 30, 1878, is a communication expressing a belief that many accidents have been caused by this defect. And the writer speaks of one case known to him, where an engineer who had had many narrow escapes, finally proved to be color-blind, and acknowledged the fact. But each of these narrow escapes might have been a disaster, and the case shows the need of examination as clearly as if fatal accidents had occurred.

The investigations of the board have convinced them that while danger is possible, and while all needed precautions to avoid such danger are an absolute duty, yet its extent has been greatly exaggerated. When a large per cent. of color-blindness is reported among a body of employés, great allowance should be made for the agitation and nervous excitement under which they labor when they are examined. They are called in from the open air to a room perhaps imperfectly lighted, and in the presence of strangers are subjected to an investigation which is mysterious to them, and of which they have heard that their daily bread and that of their children may depend upon its result. While they are thus "on trial for life" they often make mistakes which wholly misrepresent their capacity for distinguishing color, and which give a false idea of their general intelligence.

Of course, if it is unsafe to employ a man afflicted by color-blindness, he must be discarded. It would be false sympathy and misguided pity that would retain him. But it would be at once foolish and cruel to remove three or four per cent. of our railroad employés from their places, if they are in fact fully qualified to perform their duties.

The use of the phrase "color-blindness" tends to mislead. It is applied to all persons whose sense of color is in any way deficient. The word "blind" is not so used, as applied to men whose vision is defective. We do not call near-sighted persons "blind." As all would agree that blind men are not fitted to run an engine, so without an explanation of the term, it would seem plain that color-blind men, especially when afflicted with "complete color-blindness," should not be employed, when it is necessary to distinguish the color of signals. But the word as used by specialists, includes persons who, in the ordinary walks of life, and in their special employment on railroad trains, do, habitually and accurately and without failure, distinguish all colors, but who, upon examination, sometimes erroneously select as having a green or red tinge a "color of confusion." And knowing this, we may well hesitate before we reject from railroad service, all who are pronounced "color-

blind." Professor Holmgren himself says: "He whom we call color-blind is not, correctly speaking, at all blind to colors.

The public are also liable to be misled by witnessing experiments with persons totally color-blind. There are a few such persons; and their efforts to select and match colors furnish a striking and amusing exhibition. When we see green matched with scarlet, or a bright red skein of worsted confidently described as black, we are naturally impressed with the visual imperfection of the person on trial. And when we are told that four or five per cent. of the male population have this defect, and that up to this time, there has been little or no examination of railroad employés, the effect is to shock and alarm us. But the alarm is diminished when we learn that out of a hundred persons whom science declares to be "color-blind," not one may be incapable of rapidly and correctly distinguishing one color from another.

It is also to be remarked that color-blindness does not imply indistinct vision in other respects, but is often attended with a quicker perception of faintly illuminated objects. And it is another ascertained fact, the reverse of what some might expect, that color-blindness partially disappears when colored objects are illuminated by artificial light. And, therefore, "contrary to common belief, our present railway signals are safer, so far as liability to mistake by the color-blind is concerned, by night than by day." But it is added, "though safer they are not safe."

This is one reason why persons who have been pronounced to be color-blind, prove, on examination, to have full perception of the colors of lanterns when placed at great distances and under trying circumstances. Such has been the experience of the commissioners who have thus experimented on railroad employés who are theoretically color-blind, and who promptly distinguished white, red, blue and green lights at a great distance, while engines were going out and coming in, with all the attendant annoyance of smoke and steam. The same men, also, distinguished by daylight, red, green, and white flags, at a like distance without failure, while a person totally color-blind who happened to be present on one occasion, pronounced a scarlet flag to be black, when it was held directly before his face.

One explanation of this combination of theoretic color-blindness with real and unerring sharpness of color-vision, may be found on examining the plates and directions used by scientific men to illustrate this subject. In Professor Holmgren's plate, as published by Dr. Jeffries, will be found the green test I followed by five "colors of confusion." And on p. xix, it is said: "If the person examined takes any of the confusion colors (1 to 5) to put with the green, he proves himself color-blind; *or even if he seems to want to put them together.*" But No. 1 of the confusion colors seems to many persons of perfect vision—perhaps to a majority of them—to contain, mingled with gray, a slight tinge of green. And this incident occurred at one examination. A railroad employé had shown great readiness in picking out different shades of green, and finally selected a skein of worsted corresponding to No. 1. Upon this, an expert in color who was present, remarked that the man was also an expert, and declared that he was the keenest in vision of all that had been examined. Yet, this man had proved himself to be technically color-blind, and so, unfit to earn his living by doing his daily work on an engine.

It is said of some of these "color-blind" persons who run engines with success, that they "guess" at colors by the varying intensity of light,—that they do not see colors properly or as persons of normal sight see colors. But if they always judge rightly no one cares whether they see as we do, or not. Dr. Holmgren says: "Just how a color-blind sees a color it is not possible to decide; for it is a subjective sensation." The only practical question is, whether these persons in fact, can rapidly and unerringly distinguish one color from another.

It is suggested that, when men judge of color by the relative intensity of light, they are liable to be misled, when fog, or sleet or smoke obscure a signal lantern, and so diminish the intensity of its light. And this would seem to be a reasonable suggestion. Thus Dr. Spalding, who

examined the men employed on the Maine Central, is reported as saying, that to a color-blind man a fog may turn a red light into green. But he does not state as a fact that this ever occurred. And in regard to a color-blind engineman, whom he examined, the testimony was that he never failed, under any circumstances, to distinguish red signals from green. Nor is any case recorded, so far as is known to this board, of a "color-blind" man who could distinguish red lights from green in clear weather, and who has mistaken red for green in foggy weather.

The commissioners tried a number of experiments upon persons who failed in the ordinary tests of color perception, by placing at distances of five hundred or seven hundred feet, red lanterns muffled, doubly muffled and obscured by a smoke-colored fabric; with the idea that this artificial obscuration of light would have the like effect with that of snow, or sleet or mist. But in no case did any man, who could distinguish the lights at that distance, confound the obscured light with green, or hesitate to decide rightly on the color. A smoked white glass was used with the same effect.

But the one man who was found unable to distinguish colored lights at a distance, did repeatedly mistake a muffled red light for green, and also a smoked white lantern. It might be thought that he always guessed at random and only happened to repeat these errors. But he repeated them on more than one occasion, and it seemed that there must be a special cause for these special blunders. His case seems to confirm the theory that persons really color-blind do judge of colors by their relative intensity, giving them names associated in their minds with that degree of intensity. Such a man would, of course, be utterly unfit to take any part in running a train; nor would he be so employed by any manager cognizant of his defect.

The effect on the vision of color-blind persons of increasing or reducing the intensity of light has been differently stated. A case has been recorded of a red-blind man who could, for his eyes, change the white light to green by screwing down the wick, and who made it red by screwing it down yet further. But to most persons red seems more brilliant and intense than green; and so it is stated by Professor Holmgren, speaking of all the color-blind. In another portion of his work, however, he says that to the green-blind green is weaker than red, while to the red-blind red is weaker than green. Probably all the peculiarities of this defect are not yet known; and the commissioners regret that this season has not yet afforded them opportunities for trying practical experiments on color-blind persons in snowy or even in very foggy weather.

It has been suggested, that in railroad matters all difficulty on the score of color-blindness might be removed: (1.) By selecting other colors as signals, and by discarding red and green; or (2.) By using signals differing in form instead of color, in order to indicate danger and safety. But it has been proved to be impracticable to dispense with red and green. Blue is objectionable because blue glass intercepts so many rays of light that it becomes very feeble, and can only be seen at a short distance; yellow is too near akin to white, as all white lights have some yellow; black is of no service at night; and it need not be said that night signals are the most important.

Nor can form alone be well used to designate safety and danger, because a difference in color is seen sooner than a difference in form, and more persons would fail to distinguish form at a distance than would fail to distinguish color. Of course a difference in the form of signals, as well as of their position, may be used as an auxiliary to the difference in color, and both are so used with good effect; but the whole body of railroad men and managers would protest against discarding green and red as signals.

Efforts not wholly unsuccessful have been made to remedy the defective vision of the color-blind by the use of colored glasses, or of glasses enclosing a colored liquid; but up to this time no device has been found that would be satisfactory in case of real color-blindness. A similar statement may be made as to the special education of color-blind persons. Something may be done to diminish the defect, but no amount of education in color would fit a person

really color-blind to drive an engine; and the board agrees with Professor Holmgren in his conclusion: "As long as the existing system of signals used on railroads is considered in almost all respects the best known, it is indispensable that no one incapable of rapidly and accurately distinguishing red, green and yellow should be allowed to fill any position on railways involving any connection with colored signals." The question which has been found difficult to decide is: Who are so incapable?

A brief statement of the laws and practice in various countries as to examinations may be of some value.

In England no law exists which requires examination; but the principal railroads, and perhaps all, examine their employés for color-blindness, and accept no engine-drivers or signal-men without previous examination. The method, however, is simple; few men are rejected, and the tests applied are not considered as sufficient by those especially interested in the subject.

In the Cunard line of steamers an examination is held previous to every departure of a steamer from Liverpool. This is done simply by holding a board, marked with various colors, at a short distance from the person examined, and asking him to name them. The examination is made of common sailors as well as of officers. In the Leyland line all candidates for position as master, first and second mate, are examined as to their knowledge of colors by the same person who examines in navigation. Pieces of glass are used, colored green, dark green, red, blue, sky-blue, yellow (dark and light), and white.

In Sweden, no law has been passed compelling an examination, but no one is allowed to enter the service of the state railroads until he has been found faultless in the faculty of discerning colors. Since 1876 all have been examined, nearly three per cent. being found more or less defective.

In Holland, the regulations require examination for railroad employés, as well as for the naval and mercantile marine.

In Germany, examinations have been officially recommended, and they have been made, but not in a manner satisfactory to those who have made the matter a specialty. The tables, as republished by Dr. Jeffries, show that only 319 color-blind persons were found among 41,444 examined, being considerably less than one per cent.

In Italy, no regulation is published, but inspectors examine applicants for employment as to their power of distinguishing colors by natural light, and by lamp-light. Apparently the examination is practical, and not scientific or technical.

In France, no law seems to have been passed, but examinations are made on many of the railroads.

At the meeting of the International Medical Society, held this year at Amsterdam, a code was reported by Professor Donders for regulating this matter, and was recommended by the society.

In this country, examinations have been made by many railroad companies since attention has been called to this subject. Dr. Keyser, of the Wills Eye Hospital, is reported as having examined in eight months all the employés on all the roads terminating in Philadelphia, excepting the Pennsylvania Railroad. His report was, that three and a half per cent. "have defects of such a character as to make them really incapable and unsafe to fill the positions they occupy." He found, also, that an engine-man who was green-blind never mistakes as to the color of signals. In Maine, an examination heretofore referred to was made on the Maine Central Railroad, with results not unlike those of Dr. Keyser.

In the United States army, all accepted recruits are now examined for color-blindness, and defects are noted, but are not cause for rejection, except for the Signal Corps. Examination is made by the use of test-wools, according to Professor Holmgren's method. The object of the examination is stated as being twofold: to avoid assigning to the color blind duties for which they are unfitted; and the accumulation of facts to show whether further restrictions are needed on their enlistment. For the report on this subject the board is indebted to the kindness of Surgeon-General Barnes.

The board early became convinced that the possible dangers of color-blindness were such that examination ought

to be made at once of all the persons employed on our railroads, whose duties are in any way connected with signals. A circular was accordingly sent to the president of every railroad company operating a road, asking that all such employés might be examined, and the results reported to the board. One object of this was to prevent accidents arising from color-blindness. Whatever view might finally be taken as to the extent of the danger, the mere existence of it seemed to call for action without delay. Valuable information, also, was expected from the results of these investigations. And this hope was not disappointed. Reports received from the various roads show that intelligent and careful investigations were made on most of them. The commissioners have availed themselves of the information thus obtained, and have, where it was possible, followed up the experiments by further tests of persons found defective.

A striking result of these investigations was the effect upon the railroad officials who conducted or witnessed them. There had been much scepticism among them as to the existence of color-blindness. The experiments opened their eyes to a source of danger hitherto unknown, and insured attention to this matter in the future.

The board has been criticised for advising these examinations, made by "laymen," as distinguished from medical or ophthalmological experts. But the board was not authorized to direct the employment of such experts in advance of any law upon the subject. And, what is more to the purpose, the commissioners were soon convinced that any man of ordinary intelligence could conduct such examinations—at least the preliminary ones—so as to secure practical and valuable results. Printed directions are given in various works on this subject. They may be found on a page of directions issued by the medical department of the army. These are addressed to all medical officers. But, if these investigations were as critical as they are sometimes supposed to be, only experts in ophthalmic science could conduct them; and it might be doubted whether even such experts were skilled in the specialty of color-blindness, and, indeed, whether this state contained more than one competent person. The commissioners have not felt that they were shut up to register the views of any one expert. The legislature referred the matter to three "laymen" for investigation, assuming that they were competent to study it; and they are convinced that, so far as practically necessary, any man of average sense can test an employé so far as to learn whether it is safe to trust his sense of color in railroad service. Most persons, on examination, speedily prove their freedom from defect. The army directions provide that a green test-skein of worsted shall be laid aside, and the recruit shall be requested to place alongside of it all the shades of that color. And, "*if he promptly selects the shades of green only, then, after he has thus selected eight or ten skeins, the examination may be discontinued, for he is not color-blind.*" Now, almost all persons do this; and it is evident, that, so far as this test is concerned, it can be applied by any one who is not color-blind himself. There is no mystery in the use of this test,—no need of ophthalmic or medical knowledge. When the party fails to select the right color promptly, and appears on final examination to be defective, then he may well be allowed a further critical and medical examination, to ascertain whether he is really so defective in color-sense as to be unfit for employment. This is the course pursued on one of the best managed railroads in the United States. And their experience teaches what the limited researches of the board had already shown, that color-blind men can be detected without the possession of any special skill of learning.

The most rigorous examination, and the most complete report, of which the board has any knowledge, was made by a conductor who was detailed by one of the railroad companies for this purpose. This record was made instructive and interesting by his preserving, in each instance, a portion of the worsted which the employés selected as containing the colors offered as tests. The board would not have advised the selection of a conductor, lest he should be suspected of favoritism, but in this case a result was secured which was impartial, intelligent, and full of instruction.

The circular called attention, also, to defects of vision not relating to color. This subject was not referred to the board, but it is part of their ordinary duty to report on every important matter connected with the operation of railroads. And it is a striking fact that so little attention had been given to this subject. Most railroad companies seem to employ men for places where good sight is vital, without examination; and continue to employ men whose sight is likely to be failing from age, without testing their visual power. Probably their reasoning is that of an intelligent official, who writes: "We had one engineer who was near-sighted, and removed him at once; bnt he was the only man I have ever known who could not see an object six hundred feet from him that was willing to risk his life on a locomotive. There are many persons who are near-sighted, and a small percentage of the people are color-blind; but I do not believe they prefer railroading as a means of living."

But such reasoning is unsafe; and men whose vision has gradually become defective, without being conscious of it, are found employed on railroads; and it is probable that men who know their defect are willing to risk their lives, and the lives of others, rather than to lose their means of gaining a livelihood. Members of this board, while they cannot speak of any railroad accident as resulting from color-blindness, do know cases where defective vision has led to such accidents. In one case, at least, the defect was never suspected by the person himself, until it had caused a considerable destruction of property. It was then recognized; and a new employment, not requiring vigorous eye-sight, was given to the employé.

It has seemed to the board that examination as to strength of vision was even more important than examination as to color-blindness. And this view is confirmed by Prof. Holmgren's statement: "If the system of signals were based upon form, and all persons discharged from the service of railways, who, in consequence of an imperfection in vision, could not clearly and decidedly distinguish these signals at a distance, the proportion of such would be larger than that of the color-blind" (*Smithsonian Report for* 1877, p. 172). Of course, examination as to the two points can be made at the same time; and such was the recommendation of the circular.

This view has been further confirmed by the railroad officials who have tested their men, and who have found more defective in vigor of sight than in perception of color. In these examinations, men who failed to distinguish letters at a very short distance showed themselves far-sighted and clear-sighted in recognizing signals made at a distance of three thousand feet, and even of a mile. And these employés, technically defective, appeared to be practically well fitted for their duty. This, of course, was to have been expected from well-known facts as to vision, especially with those whose eyesight is affected by old age.

The final conclusions of the board are: 1. That the existence of color-blindness, total and partial, is a well-established fact, and that there are men who, by reason of such defect, are unfit for positions on railroads requiring ability to distinguish color-signals. 2. That the extent of dangerous color-blindness, i. e., such color-blindness as unfits persons for railroad employment, has been greatly exaggerated, and that a very small per cent. of persons are, for this reason, unfit for such employment. 3. That examinations may be properly made by persons not medical experts; and that such examinations will certainly be sufficient, if doubtful cases are referred to such experts. 4. The board recommends that every railroad company shall have an annual examination of every employé whose duties require or may require capacity to distinguish form or color-signals, and that no one shall be so employed who has not been thus examined. The examination should refer to color-blindness and to other defects in vision. It should include all who are in any way concerned in the movement of trains. 5. The board does not recommend legislation on the subject. The interest of each corporation is strong enough to insure careful examination. Humanity would prevent any company from knowingly employing a person whose defective sight might at any time cause a fatal accident. And self-interest will make railroad managers careful in avoiding

even false charges that accidents have resulted from such defects.

The failure to make examinations heretofore is owing to the want of information on the subject; and, in regard to color-blindness, to the general incredulity as to its existence. Information is now generally diffused, and incredulity has ceased, thanks to the efforts of scientific men. And there is no reason to fear that due attention will not be given to the recommendation that all applicants for employment on railroads, and all persons employed, shall be examined for defects.

PRODUCTION AND TRANSMISSION OF POWER BY ELECTRICITY.

By GEORGE W. BLODGETT.

From Papers of Boston Society of Civil Engineers.

The successful introduction of the electric light for practical use, the many inventions involving one or another of the applications of electricity, together with a popular interest in the many practical uses to which it can be put, make an examination into the methods, economy, and cost of its production and distribution, highly opportune. It is only within a few years that means have been devised to produce electricity in large quantities cheaply enough to come into use, even for lighting purposes. Now there are companies which engage to light mills, manufactories, and large areas, and guarantee the cost not to exceed one half that paid for gas, for the same premises, and furnish a better and purer light. Electricity is likely to be economically applied for many other purposes for which it is not now used.

It is not my purpose to discuss electric lighting, or the questions of great scientific and practical interest connected therewith; but since electric currents used are almost always generated by mechanical power, a description of some such machines, the mode of working, the degree of efficiency attained, and the relative merits of each type of machine which has been practically tested, may not be uninteresting. The sources from which electricity can be derived are almost innumerable; those best known being batteries of many kinds, frictional machines, thermopiles and electric machines. It is only the last which have been economically used for the production of large quantities of electricity. I ask you to take for granted that large quantities of electricity can be generated cheaper and more conveniently by mechanical means, than by chemical action or by friction. There are many kinds of machines, in all of which there is one important principle, known as the principle of induction. Machines can be divided into two classes: those that employ permanent magnets, and those in which the electricity which the machine generates is made to pass through long coils of wire which surround cores of soft iron, making the iron strongly magnetic, and forming what is known as an electro-magnet. Machines of the first class are called magneto-electric, and those of the second class dynamo-electric; their history is briefly as follows:

In 1819, Oersted, a Danish physicist, discovered that a current of electricity flowing in a wire near which was placed a magnetic needle caused a deflection of the needle.

In 1831, Faraday discovered that a magnet in motion near a coil of wire could generate a current in the wire.

These two discoveries, and those which followed, convinced the experimenters of that time of the general principles underlying them, which may be briefly stated in the following terms, and which is the law of the relations between electricity and magnetism:

I. Any variation in the electrical state of bodies can produce a magnetic disturbance, and any change in the magnetic condition of bodies produces corresponding electrical variations.

II. Magnetism may be induced in bodies capable of magnetic influences by magnets, and electric currents may be induced by the action of electric currents in other bodies.

The currents in magneto-electricity are called "induced," to distinguish them from those flowing from a battery, because they are usually not continuous, but are the result of a previously determined set of conditions. The first machine the writer has found any description of, caused a horseshoe magnet to revolve in front of the ends of a double induction coil. This was constructed by Pixii, in 1832, and was improved by Saxton, and afterwards by Clarke, who revolved the coil instead of the magnet.

Very large magneto-electric machines have been made, notably those used in some of the light-houses in France. They were of the type known as the Alliance machines, employing fifty or sixty permanent horseshoe magnets, each capable of sustaining sixty or seventy kilograms. The objection to magneto machines is the limit of the power and intensity of the permanent magnets employed.

It has been discovered that an electric current circulating in a wire wound spirally around a piece of soft iron, renders it strongly magnetic so long as the current passes. By increasing the number of the turns of the wire, the strength of the current, and by properly proportioning the dimensions of the coils and of the iron cores, we can obtain magnets of immense power. The Stevens Institute of Technology, at Hoboken, possesses one said to be capable of lifting several tons.

The Gramme, Siemens, Brush and Farmer-Wallace machines are what are called dynamo-electric, and are those in which electro-magnets are used instead of permanent magnets, having corresponding increase in power.

In order to obtain mechanical motion by electricity from these machines, it is necessary to reconvert the current, transformed from mechanical motion back into power.

To accomplish this, a second machine is necessary, which must be connected with the first machine by suitable conductors, and from which the power can be taken off for the purposes required. The power recovered depends on the size and kind of the machine, and the electro-motive force of the current.

Electro-motive force of a battery or machine may be defined as the power it has to overcome resistance. If we compare an electric current to a stream of water, then we may say that the electro-motive force corresponds to the volume multiplied by the head; or if E equals the electro-motive force, C the quantity, and R the pressure or head, then $E = C \times R$.

The greater the electro-motive force of the current—that is, the power to overcome resistance—the greater the effect produced on the second machine. It has usually been supposed necessary that a large quantity of electricity should be conducted from one machine to the other, and hence some have supposed electric transmission impracticable because of the great size of conductors necessary. For instance, one prominent electrician asserts that a conductor of sufficient size to transmit the power of Niagara Falls a distance of five hundred miles would require more copper than exists in the deposits of Lake Superior. Another estimates the cost at $60 per lineal foot. A very interesting discussion relating to the above, by Messrs. Houston and Thompson, is printed in the January, 1879, number of Journal of the Franklin Institute.

We come now to the question, how high a rate of efficiency can dynamo-electric machines produce, and what percentage of the power applied to the pulley of the first of two coupled machines can be recovered at the pulley of the second machine?

Like most other machines, there is a wide limit of variation in the performances under favorable and unfavorable conditions; and even under the same conditions, different machines produce various quantities of electricity. Dr. Paget Higgs has obtained from a Siemens machine about ninety per cent. exclusive of friction. Prof. Trowbridge obtained seventy-six per cent., also with a Siemens machine, which he states to have been running below its normal speed. The veteran electrician, Moses G. Farmer, in a private letter, says: "I have obtained as high as eighty-five per cent.; others claim more; some may go as high as ninety per cent. under especially favorable conditions; but from seventy to eighty per cent. is a fair amount."

It appears that the Brush machine has given as high as eighty-seven and four-tenths per cent. The remainder of the

force is expended in driving the machine and producing local currents in different parts of the machine, which currents ultimately manifest themselves as heat, principally in the armatures in which the local currents are for the most part produced.

In order to get the best effect from an electric machine, the external and internal resistances must be equal. If the internal resistance of the machine be greater than that of the external parts, then a larger part of the current produced will be used in internal work, eventually appearing as heat in the machine. If the internal resistance be too small, the current developed will be below what might be obtained from the machine.

We are not to conclude that a machine which heats badly, when working through a small resistance, is therefore inefficient. We should first try the machine with proper external resistance interposed. In coupled machines the greatest strength of current passes through the conductor when the second machine is at rest. As soon as the machine starts, an electromotive force is developed in a direction contrary to that of the first machine, which tends to neutralize the current in the conductor. The greatest work is obtained from the second machine, when the number of revolutions per minute equals half that of the first machine. Experiment has borne out the theory in this respect.

In an admirable little work on the "Electric Transmission of Power," by Dr. Paget Higgs, is given the results of a series of experiments on machines running at different speeds, with the result, when the first machine made eleven hundred revolutions per minute the maximum effect was obtained, when the second machine made five hundred and one revolutions a minute in one series of trials, and six hundred and twenty-five in another. Also when the first machine made fourteen hundred revolutions, and the second six hundred and ninety-one, the maximum per cent. was obtained. These per cents. were thirty-nine, forty-five and forty-nine, respectively.

Let us now examine briefly some instances of the actual employment of electricity as a means of transmission of power. On May 26, 1879, a field was plowed at Sermaize, in France, by means of power transmitted four hundred and six hundred meters.

At the Berlin Exposition, 1879, there was in operation a railroad three hundred meters long, run by electricity furnished by a machine working in the large hall. This distance was traversed in two minutes by a train consisting of a locomotive and three wagons, in each of which six persons could be accommodated.

Sir William Thompson transmitted eight or ten horse powers more than a mile by an electric current.

Dr. Paget Higgs, in a letter, furnished me some interesting unpublished data which I am permitted to lay before you, as follows:

"The later experimental trials, of which I spoke to you, were concerned with much larger powers, and in transmitting ninety-eight horse powers, ten machines were at first employed; these by subsequent improvements were reduced to two at each end of the wire. The wire, of copper, was three-eighths of an inch in diameter, and was suspended on ordinary posts. The source of power was a head of water made available by means of a turbine. Our first machine was driven at nine hundred and fifty, and the second at four hundred and fifty to four hundred and sixty revolutions a minute. No return wire was used; the earth was employed to complete the circuit, but the earth plates were constructed on a somewhat novel manner. The distance, two and a quarter miles, is, I believe, the longest distance power has been transmitted at so high a percentage as forty-eight per cent. reclaimed. All measurements were by dynamometer, taken during actual running and not specially measured. The cost of machines and conductors, exclusive of the turbine, was twenty per cent. less than the estimated cost of putting in new boilers and new boiler house to work an existing steam engine. Please note that the machines and power require no attention, no stoker, no fireman, no fitter, and are lubricated about as often as an ordinary shafting. It is intended to double the power."

Finally we may sum up as follows:

1. Electrical transmission of power is always possible, and can be applied when hydraulic power, compressed air, and

wire rope transmission would be impossible

2. An efficiency of seventy-five or ninety per cent. may be counted on in the transformation of power into current.

3. About forty or fifty per cent. of the power applied to the pulley of the first machine can be recovered at that of the second.

Thus far the machines used at both ends of the line have been substantially alike. It is possible changes in them may show better results.

The ideal machine would be that in which the friction and resistance to the air are a minimum, and in which the ratio of internal work to external work is as small as possible.

As great a surface as possible in the armature should be exposed to the air, in order that the heat developed may be radiated as rapidly as possible.

THE ADULTERATION OF PORTLAND CEMENT.

From "The Building News."

One of the most important constructive agents of modern times is in danger of degradation from the insidious action of fraudulent parties anxious to secure high profits by the agency of adulteration. For more than a quarter of a century slags of various kinds have been used to mix with this cement—before an accurate knowledge of its manufacture had made much progress. The intention of such admixture had a two-fold object, one being to check the tendency of a cement of light weight to expansion, and the other to meet the advantages which the increased specific gravity of the slag secured where cement was sold by the ton. Such expedients were only adopted, however, long anterior to the general use of the testing machine, and the practice remained unchallenged until it was found that the increasing quantity of the adulterant resulted in a weakening of the tensile and compressive value of the cement, rendering its use questionable, and even dangerous. The beginning of this method of introducing foreign substances into a powder of Portland cement has had most pernicious results, for it encouraged the idea (not yet exploded) that sand and similar materials continue to be used for improper purposes; and, curiously enough, the best cements, which were made specially heavy, raised the greatest amount of suspicion and doubt. The cause is readily understood, for imperfect grinding left a large percentage of residuum incapable of reduction, which in character and appearance resembled coarse sand, reduced slag, or comminuted stoneware, although highly improper and undoubtedly fraudulent, such additions in moderate proportions were only negative in character and simply pre-occupied so much space which would have been more cheaply, if not more beneficially, absorbed by the sand of the mortar mixture. The more recent and continuing application of the slag adulterant is in some measure due to the improved quality of Portland cement now generally manufactured, which leaves a considerable margin between the presented tests and its actual strength. The distiller reduces the products from his still by an addition of water to level the spirits to the acknowledged standard; and, when he exceeds or falls short of its level or datum, arranges its price accordingly; but when the adulterant is pure and innocuous, no objection need be made. The cement-maker, who, by the liberality and ingenuity of his system of production, can readily exceed the maximum tests imposed by his customer, may also, like the distiller, reduce the strength of his powder to the standard by which he is assessed. The more economical means to adopt would be to reduce the fuel cost; but in this direction he is sometimes unable to protect himself from being under the obligation to give cement of a high specific gravity; so that, while fulfilling the conditions in one direction, he is saddled with an excess of strength or loss to him in another. A cement weighing 112 lbs. per bushel, when accurately powdered, can readily

meet the requirements of a test of 350 lbs. to the square inch; but the weight standard may be, and frequently is, 118 lbs. per bushel, so that the difference against the maker under such circumstances is exceptionally hard and unreasonable. During a period of high prices, such an anomalous condition of things does not press so hardly on the producer, but when successive competition and low prices occur, recourse is had to improper means to maintain profit. He has now reached these times, and the correspondence and discussion at present prevailing on the question of adulteration of Portland cement with slag indicates that it will, if it has not already attained dangerous proportions.

Slag produced in the iron industry is abundant in many districts of England, Wales and Scotland; but at present it may be regrarded as a worthless waste, notwithstanding the more or less successful attempts for its utilization. Its chemical value and resemblance in analysis to a good Portland cement indicates its suitability for purposes of adulterating that article, and the charge is made that it is now used extensively for that purpose. If so, in the interest and protection of the constructive profession and the public generally, a chemical test will have to be instituted to guard against the dangers of such a combination. We shall shortly state why such a course is imperatively necessary to check the use of so undesirable a compound as Portland cement and iron slag. Slags are of various kinds, according to the quality of the ores from which they are produced, and the fuel and fluxes used in the fabrication of the pig iron. The best and least objectionable, however, have, in their chemical constitution varying quantities of protoxide of iron, sulphide of calcium and magnesia, all of which are, even in moderate amounts, unsuitable; and we may say unsafe, to mix with Portland cement. In their physical characteristics slags have a strikling resemblance to Portland cement "clinker," as it comes from the kiln, and, when reduced to powder, are still more similar in color and general appearance.

In cost, however, there is a great difference in value, and hence the temptation to adulterate with slag. The majority of slags when added to the "clinker" and ground together through the millstone, induce an energetic initial set of the powder, and generally realize high tensile breakings when the briquettes are kept out of water. Under the action of water, however, but sometimes very protracted in its character, the dangerous quality of the obnoxious ingredients named becomes apparent in the gradual degradation of the sample. We could not give a better illustration of this action than is to be seen in many districts where the slag heaps are *dusting;* and, indeed, in some of the earliest mounds, so much so has this progressed as to enable the surface to be used for agricultural purposes. The soil thus produced is found to be a fertile one, for it contains the best elements of fertility in the silica, lime and alkalies. They are, however, in a concrete or mortar mixture, dangerous ingredients: and in structures (more especially in those under water) where they are employed, the same influences which degraded the slag will ultimately reduce to powder the most elaborately-fabricated mortar. The use of slag, therefore, in any form, either as a silica agent in the manufacture of Portland cement, or as an adulterant in its finished state, should be avoided, unless some preliminary treatment of purification or elimination of the obnoxious ingredients referred to has been resorted to. We have no experience of what can be done in this direction, but we think to get rid of sulphide of calcium would involve so expensive an operation, even under the most successful circumstances, as to preclude the chance of its being resorted to—at least, for the adulteration of Portland cement.

Although Portland cement has, during late years, been made of good quality, and the fortunate rivalry amongst engineers to secure a first-class article has resulted in much good, there is still in some quarters a feeling of unrest and desire for something novel. Eccentric machines for testing, or senseless methods of treatment of the briquettes to be tested, seem to have been followed by mixtures of discordant ingredients in the belief that Portland cement can be *improved.* The simple and inexpensive character of the raw materials for producing a good cement, and the now well-known processes by and through which

it is fabricated, preclude the possibility of introducing any cheaper material capable of producing like results at equal cost. If any improvement is to be realized, it will be found in the direction of the fuel cost and machinery of reduction, which departments of this industry are having due and reasonable consideration. Chalk and clay are, indeed, so plentiful in this country that there is neither immediate nor remote chance of their rising much in value. No substitute for one or the other can be found more suitable, and the builders may well feel confident that good cement from these materials can be at all times forthcoming to meet their most extended demands.

In these remarks we have assumed that many of our readers are well acquainted with the process of making Portland cement, or, at all events, understand that there is no secret in its practice, neither is there any risk in using it when they practice the most ordinary and well understood rules for testing its quality, and guarding against its dangers when imperfect. Although this well-known cement has only been known by its general name of Portland, the rudimentary experiments which led up to its discovery may be said to have been originated by Smeaton in the middle of the last century. In his Eddystone experiments he proved that the hydraulicity of limes was due to the presence of *sand* or *clay* in their original mineral condition. Biat in France, and Pasley in this country, followed on Smeaton's lines, and Aspdin, in 1824, boldly—at least, for such a humble investigator — boldly adopted all previous knowledge, which, added to his own, culminated in his obtaining Letters Patent for the manufacture of Portland cement. The simple task of rendering ordinary limestone dust or mud hydraulic, capable of setting under water, was easily performed, and more especially when the easily-combined chalks and river clays were operated upon. The blunders committed by the early makers were due to the want of chemical knowledge, which could define with accuracy the exact proportions of the carbonate of lime (chalk) and silica and alumina (clay or river mud). The means adopted were varied, according to the experience of the operator; but usually the accurate admixture was accomplished with water as the combining vehicle. There is a gradual lessening of the hitherto objectionable amount of water so employed, and at some works on the Thames the barest quantity is now used, resulting in a considerable saving in cost. Additional machinery of a special character performs in a much less space of time the same desirable and indispensable combination or blending of the raw materials. A process which originally occupied several months in its performance can now, with equally beneficial results, be performed in a week or ten days.

Instead of differences in the mechanical tests for proving Portland cement, we should advise the adoption by all consumers and producers of one common standard, and thereby facilitate the comparison of qualities, and thus avoid differences which, under existing circumstances, are practically irreconcilable. If an approaching danger like that we have referred to should attain serious dimensions, or its progress become incapable of being checked, a new chemical test must be prepared to stultify its effects and render abortive the schemes of the dishonest or misguided adulterators. If we will have adulterated cement, let its sale be controlled by some such rules as regulate the sale of butter, and other articles of daily consumption.

In what we have said in reference to this question of the use of clay we wish it to be clearly understood that we do not object to its use as a constructive agent. As an aggregate, under certain controllable conditions, iron slag can be made exceedingly useful; but we protest against its being used as a binding agent of either mortar or concrete. In the concreted mass, wherein it only plays a comparatively subordinate part, the extent of danger, where it may exist, can be readily measured and controlled, which cannot be done when it is intimately incorporated with the cement.

ASPHALT AND MINERAL BITUMEN IN ENGINEERING WORKS.

By Mr. W. H. DELANO, Assoc. Inst. C. E.

From "The Building News."

Adopting the nomenclature of M. Léon Malo, which had received general sanction, the author considered asphalt as a combination of carbonate of lime and mineral bitumen produced by natural agency. Asphaltic mastic was the rock ground to powder, and mixed with a certain proportion of bitumen. Gritted asphalt mastic was asphalt mastic to which clean sharp sand had been added. Asphaltic or bituminous concrete was gritted asphalt mastic mixed when hot with dry flint or stone. Boussingault's analysis of bitumen gave C 85, H 12, O 3. It was, therefore, an oxygenated hydro-carburet, and quite distinct from the preparations of gas-tar and pitch, which were sometimes erroneously styled bitumens and asphalts. It was important that these distinctions should be borne in mind when specifying asphalt, as their disregard might lead to the employment of a material having few of the properties of the natural rock, although bearing, to the uninitiated, a strong resemblance thereto. Messrs. Hervé-Mangon and Durand-Claye, of the Ecole des Ponts et Chaussées, Paris, had supplied the author with detailed analyses of different kinds of natural asphalts, which were given in the paper, and specimens were exhibited. But beyond knowing the numerical value of the proportionate constituents, it was highly necessary that the engineer should be acquainted with their quality. Asphalts which gave almost identical analyses might, in practice, yield widely different results, if the nature of the individual components was dissimilar. Powdered limestone should be white, and soft to the touch; if rough, it probably contained iron pyrites, silicates, crystals, &c. The presence of these substances was prejudicial, and if suspected, the limestone should be subjected to a secondary analyses, directions for which were given. The proportion of bitumen to limestone in the natural asphalt should not exceed 10 per cent. for carriage-ways, indeed less than that was preferable. For this latter purpose no asphalt should be specified which had not stood the test of, at least, three hot summers and three cold winters. These precautions being taken, the author was of opinion that a well-laid surface of compressed asphalt, 2 to 2⅝ inches thick, on a foundation of Portland cement concrete, 6 to 9 inches thick, was superior to all other carriage-ways. It was noiseless; hygienic, being impervious to urine and the liquids from dung; absorbed vibration; produced neither dust nor mud; was cheap, durable and easily repaired, and the old materials could be used again. The charge of slipperiness, which had been made against asphalt roadways in London, was not due to the material, but to the absence of provisions for proper scavenging. In Paris, where the asphalt was regularly scraped, washed, and swept, the complaint did not arise. In support of the assertion that climate did not affect the asphalt in London, a table of humidity was given, showing the means of six years' (1873–8) observations to be—for Paris, 80.2; for London, 81.5. The cost of washing the roadways, when done systematically and on a large scale, was much less than was generally supposed, and the advantages far more than counterbalanced the expense. The author submitted a design for a portable washing and sweeping machine for use in London. Reference was made to the cost of compressed asphalt carriage-ways. In Paris this amounted, on the average, to about 13s. per square yard on lime concrete 4 inches thick, but a thickness of 6 inches to 9 inches of Portland cement concrete was much preferable. The cost of transport of the material also exercised an important influence on the ultimate expense. Details were given of various works of asphalt paving carried out by the author, with particulars of the cost of maintenance.

The quality of absorbing vibration, which was a marked characteristic of asphalt roadways, had been taken advantage of in the application of the material for the foundations of machinery running at high speed. This was instanced in the case of a Carr's disintegrator, which, being mounted in a pit lined with bituminous concrete, was worked at 500 revolutions per minute, without sensible tremor, whereas, with the former wooden mountings on an ordinary concrete base, the vibration was excessive, and extended over a radius of 25 yards. In the Paris Exhibition of 1878, there was shown a block of bituminous concrete, weighing 45 tons, forming the foundation of a Carr's disintegrator as a flour mill, and making 1,400 revolutions a minute, a speed which would have been impracticable on an ordinary foundation. Extensive applications of the material for this purpose obtained in France, especially in connection with steam engines and steam hammers.

Another use of asphalt was for the flooring of powder magazines, where its non-spark-emitting character made it particularly valuable. It was also largely applied in France, in the form of gritted mastic for the flooring of casements in fortifications, and in its pure liquid form, for the coating of vaults and arches, where it protected the masonry from damp, and the subsequent disintegration caused by infiltration and by frost.

In conclusion, the author referred to the imitation asphalts occasionally brought forward, and by some regarded with favor on the score of cheapness. The best of these, if properly made, was as dear as the natural material, without in any degree possessing its special qualities of appearance and durability; and in no case were any of them suited as paving materials to resist heavy traffic. In Paris, the tricks of irresponsible paving contractors were many, and necessitated constant vigilance. Inferior cement was put into casks bearing established brands, and the concrete made with such cement was put down in thinner layers than was paid for. The author had even known cases where the concrete was omitted altogether, a layer of common mortar taking its place. Such foundations would insure the failure of the best asphalt, which ought to be considered only as a wearing surface or armor to the concrete. But the mode most difficult of detection was the ostentatious display, at the sight of the works, of cakes of the particular asphalt specified, while an inferior material was in the boilers. Once laid, wear alone would reveal what had taken place. From these malpractices asphalt had occasionally suffered unmerited condemnation, but the author claimed that with *bona fide* materials and workmanship, satisfactory results could always be obtained.

ON MAGNETIC CIRCUITS IN DYNAMO AND MAGNETO-ELECTRIC MACHINES.

From Papers of the Royal Society.

A LARGE amount of magnetism is retained by the soft iron cores of electro-magnets, when arranged so as to form a complete magnetic circuit; and sparks and other indications of the passage of an electric current can be obtained at the ends of the helix wires surrounding those soft iron cores, each time the masses of iron are separated, and the closed magnetic circuit opened. In order to procure a spark, the breaking of the circuit must be effected suddenly, either by a jerk, tilt, or sliding movement.

In the case of the 58 lb. magnet described in our former note, the current that is capable of causing a spark, although only momentary in duration, is found to be sufficient in quantity and intensity to magnetize a small electro-magnet, weighing, with its coils, between 5 and 6 lbs., enabling it to sustain its own weight for any indefinite length of time when suspended by its armature.

When the armature of the small magnet is placed at the distance of $\frac{1}{8}$ in. from its poles, in such a manner as to be free to move, the instant the armature of the

large magnet is suddenly tilted or slid off it darts to them, the completion of the circuit of the small magnet being signalled by a smart click. The rupture of one closed magnetic circuit is thus caused to produce another closed magnetic circuit.

But when the interval between armature and magnet, whose circuit it was intended to close, exceeded $\frac{1}{4}$ in., the former was not attracted with sufficient force to overcome the friction of the table upon which it was resting.

The mode of removing the armature from the large magnet appeared to be of no moment, but the time occupied by the removal had much influence upon the amount of magnetic force manifested in the smaller circuit. This was particularly the case if there were an interval, no matter how small, between the armature and the poles of the magnet round which the electric current was sent.

For example, if with an interval of 1-16th of an inch between the armature and the poles of the small magnet, the armature of the large magnet was slowly slid off, the magnetization of the small magnet never rose to a sufficient intensity to draw its keeper to itself, whereas, when the sliding took place rapidly, the small armature was strongly attracted as above mentioned.

The largest amount of magnetization was bestowed upon the small electro-magnet by the interaction, when it was held upright, its poles being completely covered by a closely-fitting armature. And it was also found that when thus set up in preparation for the formation of a closed magnetic circuit, the magnetization was produced by a much slower motion of the large armature than when the small magnet had its circuit partly open. When the circuit was completely closed, if the large armature were twisted off by a slow equal motion, in such a manner that both poles were uncovered at the same time, then the small magnet could be made to sustain not only its own weight (between 5 and 6 lbs.) but an additional 3 lbs. also.

During the passage of the electric current, obtained by the forcing open of the closed circuit, the fall of magnetism in the large magnet itself is checked, the direction of its magnetic polarity remaining unchanged, the current checking or opposing the fall being in the same direction as that from the battery which caused the primary magnetization. If the ends of the helix wires are not connected together, this effect is not obtained.

Electric currents, though of less intensity and quantity, can be produced in the helices of electro-magnets, without altogether breaking up the closed magnetic circuits. For instance, with the 58 lb. electro-magnet, the circuit being completely closed by its armature, and the helices being connected with a galvanometer, a very slight pull applied to the armature produces a current of electricity, giving a considerable deflection of the needle in the same direction as the battery current; and the stronger the pull the greater the deflection of the galvanometer needle, up to the point at which the magnet is lifted from the ground, after which no further motion of the needle is produced, unless the magnet is subjected to additional strain. Thus, hanging a 4lb. weight upon the uplifted magnet produced deflections in the same direction as the pull on the armature, and on removal of the weight, produced reverse deflections.

Trying the same set of experiments with a very small electro-magnet, so that we might proceed to absolute rupture of the closed magnetic circuit without danger to the galvanometer, we found that the addition of successive weights to the magnet, while hanging suspended by its armature, produced successive deflections of the galvanometer, the needle coming to rest at zero after each addition, as in the case of the large magnet.

When the maximum weight which the magnet was capable of sustaining was reached, and a real movement of the armature commenced, the induced current in the helix of the electro-magnet was very greatly increased by the addition of even the smallest weight.

From these experiments it may be inferred that in like manner as the passage of an electric current round a bar of iron produces elongation of the bar, so the elongation of the bar produces in its turn an electric current in the helix, which tends to strengthen the magnetization. It also appears that a magnet is absolutely stronger under tension than when at rest.

On the other hand, pressure on the armature, either continuous, or sudden and momentary (a blow, for example), causes an electric current in the helices in the opposite direction to original magnetization, or, in other words, against magnetization; tending thereby to weaken the power of the magnet.

The 58 lb. magnet in closed circuit was hung by its armature, and on afterwards connecting its helices with the galvanometer no current could be detected, but on lowering it until it rested with its whole weight on the ground, a current, in the direction of demagnetization, was produced giving a deflection of 15°. In the same way, a current in the direction of magnetization was obtained, giving a deflection of 15°, by the application of sufficient strain to lift the magnet off the ground, and this result was invariable. The degree of swing, however, depended upon the rapidity with which the magnet was either raised or lowered.

It may be remarked that whereas any very slight application of force by pulling on the armature was sufficient to cause a current in the helices giving a deflection of 5° to 10° of the galvanometer needle, a great amount of pressure is necessary to produce a similar deflection. A slight pull with the finger and thumb in the one case was equal to the pressure of a hundred weight in the other.

By the momentary removal of the armature, the closed magnetic circuit is broken, and though by its immediate restoration a new closed circuit is formed, nevertheless the tension on the molecules of iron by the magnetic stress is very greatly reduced. Under these conditions, a very slight pressure upon the armature produces a great swing of the needle, whilst a pull produces scarcely any effect at all, until actual movement of the armature takes place.

If the pressure on the armature is great and continuous, a point is soon reached at which a slight pressure is no longer effective.

The effects produced are somewhat different if pressure is applied unequally. For instance:—a weight of 7 lbs. placed on the armature over the north pole of the 58 lb. magnet caused a current in the helices giving a deflection of 20° at the galvanometer. The same weight on the south pole gave the same deflection in the opposite direction. Pressure of the hand produced like swings of the needle, proportionate to the force used, and the amount of swing can be easily controlled, and the needle brought to rest by judicious pressure on either pole of the magnet.

If a lateral pressure be applied to one side of the armature between the poles, and the needle swings, say 50°, on removal of the pressure, a current is produced in the opposite direction, and the reverse swing, in place of being 5°, will be 8°, and so on, in proportion to the amount of force made use of.

With the small magnets, pressure gave no recognizable current without actual movement of the armatures.

Under certain circumstances, the attractive force of electro-magnets in closed magnetic circuit is found to increase with lapse of time. For example:—A small U-shaped electro-magnet, with limbs 6 in. long, having a core of $\frac{3}{4}$ in. iron, and helices consisting of four layers of No. 16 covered copper wire, when excited by four Bunsen cells, supported as an armature a similar U-shaped iron bar, but without a helix upon it, this latter remained firmly attached after the voltaic current had ceased, but the hanging on to it of an additional weight of 3 lbs. 6 ozs. instantly wrenched it away from the electro-magnet, and broke the closed magnetic circuit.

The magnet was then re-excited, the armature being fixed to the electro-magnet by being held in contact with the poles whilst an electric current, of a few seconds' duration, passed through the circulating wire. In place of immediately attempting to add any additional weight, the two iron Us were left hanging face to face, in the form of a link of a chain, for twenty-four hours, at the end of which time the weight of 3 lbs. 6 ozs. was hung on and sustained. Forty-eight hours later, an additional weight of 3 lbs. 10 ozs. was carefully added, making in all 7 lbs. sustained. Twelve hours afterwards 1 lb. more was added, bringing up the entire weight to 8 lbs. beyond that of the armature; this was suffered to remain for five days, when the system was taken to pieces.

On a subsequent occasion, the same magnet sustained an entire weight of 10

lbs. beyond that of the U-shaped armature, the weight sustained being reached by beginning with an amount well within the sustaining power of the electro-magnet wire in closed circuit, and increasing it by small additions made with intervening intervals of time varying from twelve hours to several days.

Another, and smaller U magnet was also experimented on; this weighed, with its coils, 3 lbs. 6 ozs. Its armature was a strip of soft iron, completely covering the poles, and having a hook in the center, to which weights could be easily attached.

This electro-magnet was excited by the passage, for a few seconds, of the current from two one-pint bichromate cells. On breaking battery contact, the armature failed to sustain 4 lbs. The electric current was again sent round the electro-magnet, and the armature was pressed against the poles, being carefully adjusted so as to cover them completely, and at the same time to place the hook precisely in the center, so that the pull should be fair and equal when a weight was hung upon it. By this careful manipulation, on breaking contact with the bichromate cells, the closed magnetic circuit was found capable of sustaining the 4 lb weight.

By successive additions of two oz. weights, made at intervals of a few minutes, the weight hanging to the armature was raised to 5 lbs., after which the attempted addition of 2 ozs. caused the disruption of the system.

The experiment was repeated under similar conditions, but with slightly extended intervals of time between the additions of the 2 ozs. weights. The magnet in closed circuit was made to hold 4 lbs., $4\frac{1}{4}$ lbs., $4\frac{1}{2}$ lbs., 4 lbs. 14 ozs., 5 lbs. 2 ozs., the time taken in all for the successive additions being ten minutes. The system was then left for 12 hours, when, by additions of 4 ozs. at intervals of a few minutes, the weight sustained was increased to 6 lbs. 4 ozs. Eleven hours later this was further increased to 7 lbs. 6 ozs., and two hours afterwards to 8 lbs. 2 ozs.

A still smaller electro-magnet, weighing, with its coils, 5 ozs., and having an armature consisting of a very thin slip of soft iron, when excited by one of the bichromate cells, could not be made, when in closed circuit, to sustain $1\frac{1}{2}$ lbs. at the moment of breaking the voltaic circuit. It, however, sustained 1 lb. with ease. The latter weight was, therefore, suspended, and the cell wires removed after the closed magnetic circuit was completed. By successive additions of 2 oz. weights, at short intervals of time (five minutes to ten minutes each), this small magnet could be made to sustain 2 lbs 2 ozs., but the addition of 1 oz. beyond this weight at once separated the armature and magnet. It was thought that a longer interval of time should, as in the former instances, enable the magnet to sustain a still greater weight. It was, therefore, brought into closed circuit, as before, and made to sustain 2 lbs. 2 ozs in the manner just related, and was thus left for twelve hours. Successive additions of 2 ozs. were then made to the hanging weight, until it reached 2 lbs. 14 ozs. Twenty-four hours afterwards 4 ozs. more were added, bringing the entire weight suspended to 50 ozs.

This small, soft iron magnet which, at the instant the voltaic current was withdrawn, was totally unable to sustain five times its own weight, was thus, by gradual growth of its magnetic force, enabled to hold ten times its own weight.

In the course of these experiments it was remarked that the longer the period the soft iron remained in closed magnetic circuit, the more magnetically ductile did its molecules appear to become. An electro-magnet, which had been for a few days in closed circuit, could be, after rupture of the circuit, made to sustain weights, in a fresh closed circuit, at much shorter intervals of time than if it was magnetized, after being for some time with its poles uncovered. The direction of the battery current with reference to the residual magnetism of the electro-magnets appeared to be of no moment. A magnet which had been left for some time with its poles uncovered had less residual magnetism after a momentary current had passed through its helices, than another magnet which had been in active closed circuit, even if the battery current had, in the latter case, to overcome a considerable amount of residual magnetism.

We found, moreover, that soft iron magnets retain their residual magnetism longer, and are capable of acquiring in-

creased magnetization much more rapidly after having been bearing weights (thereby keeping the iron in a state of strain), than if they have been left in their normal condition and without bearing any weight at all.

The conditions under which the closed magnetic circuit retains its force are not yet clearly established.

With the 58 lb. magnet a succession of gentle taps struck vertically with a wooden mallet upon the center of the armature, while resting on the magnet in closed circuit, in a very few moments completely dissipated the magnetic force so far as the sustaining power of the magnet was concerned.

Removal of any portion of the weight suspended to the armature of a magnet hung up in closed circuit likewise tends to dissipate the force of the circuit. For example: Half an hour after the removal of a weight of 10 lbs., which had been suspended to the armature of a U magnet for 21 days, the armature fell off on receiving a slight touch. In another experiment, a U magnet, which was capable of sustaining 7 lbs., and which had actually been suspending 4 lbs., was left for two months with the armature on only, the weight having been removed; at the end of that time a very slight shake was sufficient to cause the armature to fall of. Many other examples might be quoted to show that release from strain diminishes the magnetic force of the circuit.

In these experiments, in which the closed magnetic circuits had given way, the soft iron had been in a state of strain from which it had been released by the removal of the suspended weights. But when no weights were hung upon the armature, and the iron had never been in a state of magnetic tension, the closed magnetic circuit, so far from diminishing, increased in force. The 58 lb. magnet was excited with a voltaic current so feeble, that although the magnet could be lifted by the armature in closed circuit, yet great care was necessary that the lift should be exactly vertical; and very little force was required to slide the armature off the poles. After the lapse of a month, the armature was so firmly held that the utmost exertion of manual force could not stir it by a sliding movement, and the whole magnet could be raised from the ground, even if tilted as much as 15° from the perpendicular.

The magnetism of the closed circuit of the 58 lb. magnet disappears, after repeated up and down movements of either one or both of its helices, provided the ends of the helix wires are connected together, either singly, in two separate circuits, or together, in one continuous circuit. Every up or down movement of either of the helices produces currents in the wires either for or against magnetization, which currents apparently so disturb the molecules of the iron that the fixity of their original magnetic direction is lost.

In like manner as the movements of the armature, or the increased or diminished tension of the iron, produce currents of electricity in the helix wires surrounding the magnets, so the movements of the helices produce currents of electricity which may either magnetize or demagnetize the iron. With the 58 lb. magnet in closed circuit, the two ends of one of the helices being connected to the galvanometer, and the two ends of the other helix being connected with each other, the latter helix is moved towards the armature, a current is produced in the galvanometer helix which shows a fall of magnetization. On moving the same helix away from the armature, a current is produced in the direction of magnetization.

In another experiment, 30 yards of No. 16 covered copper wire, with its ends connected together, and so coiled that it could be moved freely from pole to pole over the armature, was placed on one limb of the 58 lb. magnet and the closed circuit established. Both helices were then brought into continuous circuit through the galvanometer.

On movement of the coil of wire from south limb to the north limb of the magnet, a current was produced showing an increase of magnetization. On moving the coil in the opposite direction, *i. e.*, over the north limb pole, and on to the south one, the current is reversed, and is in a direction which would cause demagnetization.

It appears, therefore, that any interference with the lines of force about a magnetic circuit means an interference with the magnetic circuit itself, and

points to the possibility of building up magnetic force of magnets by the mere movement of wires in these lines of force, though the coils moved need not of necessity be connected with the helices surrounding the magnets.

BRIEF ACCOUNT OF THE WOOSUNG RAILWAY.

By RICHARD CHRISTOPHER RAPIER, M. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

For many years engineers have been anxious to see a beginning of railways in China. Any success in this direction would not only open an important field of engineering labor, but would also greatly promote economical intercourse with that country. Many attempts have been made; but difficulty has always arisen from the unwillingness of the local authorities to sanction the proposed works, and from the reluctance of the Central Government to interfere with the responsibilities of its Viceroys. After much patient waiting, Messrs. Jardine, Matheson & Co., of Shanghai, and their friends, succeeded in acquiring a strip of land for a distance of about nine miles, from Shanghai to Woosung. As they possessed no compulsory powers, this was, of course, a costly proceeding, and the funds at the disposal of the committee were nearly exhausted in the purchase of the necessary land and graves. Still it was felt that the effort should not be abandoned without trial, and a small company was formed under the title of the Woosung Road Company with the intention of constructing a road, tramroad, or railroad, as opportunity might offer. In the course of the year 1875 the author submitted to Messrs. Jardine, Matheson & Co. an estimate for a railway on a small scale, which could be carried out at comparatively little further outlay, in addition to that which had already been incurred. It was also thought that, as it was doubtful how far the opposition to railways might extend, and what character it might assume, it would be advantageous for the first railway to be of moderate proportions. With this view, a very small engine was proposed to be sent in the first instance. In anticipation of some opening occurring in China, an engine had been specially built by Messrs. Ransomes and Rapier, of Ipswich. It weighed about 30 cwt. in working order, and it easily maintained a speed of 15 or 20 miles an hour. It was intended that if this little engine were not objected to, it should be immediately followed by others of eight or ten tons weight.

A contract was now entered into between the Woosung Road Company and Mr. John Dixon, Assoc. M. Inst. C.E., to complete and equip a railway on the basis of the estimate above referred to, Mr. Dixon agreeing to take a large part of his payment in shares in the undertaking. The materials were sent out in October, 1875, and arrived at the beginning of the following year.

An embankment about eight feet high, had been constructed along nearly the whole length of the line, in order to place the railway above flood level. This embankment had been made, from time to time, as the land was purchased, so as to prevent the previous owners resuming cultivation and possession.

The laying of the permanent way was commenced in January, 1876. The rails were of the Vignoles section, weighing 26 lbs. per yard, and were laid on cross sleepers, the gauge of the line being 2 feet 6 inches. The gauge was purposely fixed thus narrow, partly for economy, and partly to ensure the thorough consideration of the gauge question at the next stage of railway making. For a populous country like China, everyone concerned was in favor of the gauge of four feet $8\frac{1}{2}$ inches, but funds did not admit of its adoption for the experimental attempt.

There were about twenty small wooden bridges on the line over narrow creeks, but no works of importance. The chief item of expense was the ballast. This had to be brought a distance of about 70 miles in boats, at a cost of about 5s. per cubic yard.

The little engine began to run on the

14th of February, 1876, and was received by the Chinese with enthusiasm. There were frequently as many as ten thousand visitors in a single day to see it at work. It is noteworthy that the news of this favorable reception reached London the same evening.

There seemed now to be no likelihood of opposition on the part of the people, and the completion of the line with its permanent engines and rolling stock was pushed forward as rapidly as possible. The first four miles were opened for public traffic on the 3d of July, 1876, and the whole line was completed in August, but was not opened until the 1st of December, of that year. Of the permanent engines, two weighed nine tons, and one thirteen tons, in working order. The rolling stock consisted of two first-class, two second-class, and eight third-class carriages, each accommodating about twenty-five passengers. It frequently happened, however, that the carriages had double their proper complement of passengers without any accident occurring. Indeed, during the whole working of the railway there was no accident to life or limb, except in the case of one man who committed suicide; and no accident to property, excepting that a spark from an engine once caused damage to the extent of £90.

The daily service of trains consisted of seven each way, performing the distance of nine miles in thirty-five minutes, with two intermediate stoppages. The first-class fare was one dollar, the second-class half a dollar, and the third-class one-sixth of a dollar for a single ticket. Nearly all the passengers traveled third-class, there being only one first-class passenger and two second-class passengers to eighty third-class. The number of passengers per train averaged about one hundred, and frequently exceeded three hundred. The station masters, drivers and guards were Englishmen. The booking-clerks, firemen and plate-layers were Chinese. They were very tractable, and discharged their duties with efficiency and success.

A principal objection offered to railways in China has always been an alleged fear of depreciation of property near the line, owing to the disturbance of the "spirits of the air and of the earth." The only effect this railway had on property was the usual one, to cause a great increase in the market value of land and houses near it. The village of Kungwan, the principal intermediate station, experienced advantages perceptible at every turn. Besides the more substantial evidences of prosperity, there was at the stations a constant stand of wheelbarrows, just like an English cab-rank. Boatmen also obtained greatly increased occupation. It was satisfactory that so practical an answer was at once given to the principal objections which have been urged against railways in China.

The railway was in itself highly successful, being freely used by all classes of the community. There can be little doubt that the experiment would have been continued, had it not been for the untoward dispute between the British and Chinese Governments with reference to the unfortunate murder of Mr. Margary. This dispute gave the Chinese authorities an opportunity of alleging a grievance in the matter of the railway. The difficulty was eventually settled by the suggestion of Li Hung Chang, that the Chinese Government should purchase the undertaking. As that statesman was known to hold very enlightened views, this proposition was acceded to by the company. It was, however, exceedingly distasteful to the Governor of the province, who had to carry out and complete the arrangements. The purchase sum for the railway was fixed at 285,000 taels, or about £78,000 sterling, so as just to cover the outlay made by the company, and the final instalment was paid in the month of October, 1877.

In the meantime, Ting Futai, the Governor of Formosa, had expressed a desire to begin railway work in that island. The Governor of Nankin therefore availed himself of this opportunity to get rid of the railway of which he was now the possessor, but which he did not wish to keep. Every effort was made to avert so retrograde a step. His Excellency Kuo Sung Tao, the Chinese Minister in London, made representations on the subject, which were also indorsed by the British Government; but all was to no purpose. The railway was at the mercy of the Governor of Nankin, who was annoyed at having been obliged to arrange for its purchase, on behalf of his Government, against his will. He ordered that

the whole of the materials and plant should be sent by ship to the Island of Formosa. The shipment was carried out, but Ting Futai did not know that skilled engineers are a necessary part of any railway enterprise, and so no arrangements were made for any of the staff of the line to accompany the plant. Consequently the materials and machinery were landed in such a careless and negligent manner, that it is scarcely anticipated they can prove of any service.

There were about eighty shareholders in the undertaking, of whom about forty were Chinese, but the funds were chiefly found by the English subscribers. Mr. G. J. Morrison, M. Inst. C.E., was the resident engineer, and Mr. G. B. Bruce, M. Inst. C.E., was the honorary engineer in England.

Mr. Morrison has presented to the Library of the Institution a manuscript volume containing an authentic account of the undertaking, together with a full copy of all the correspondence which at any time passed with the Chinese authorities on the subject. This latter is of especial interest in view of the allegations which have been made to the disadvantage of the promoters of the undertaking; and it is of scarcely less interest in the glimpse which it gives of the Chinese view of such matters. This statement of all the facts affords complete evidence as to the entire *bona fides* of the company throughout. Mr. Morrison continues to reside at Shanghai, with the hope of making a substantial beginning of railways in a little time.

THE REGULATION OF THE WATERS OF THE JURA.

By C. De GRAFFENRIED, Engineer-in-Chief of the Works, Berne.

From the Proceedings of the Institution of Civil Engineers.

The country extending to the foot of the Eastern Slope of the Jura, from Entre-Roches to Solothurn, formerly presented vast stretches of marsh and of land frequently under water. These marshes and water meadows constituted, under the title of the "Grand Marais," the greater part of the country comprised between lakes Morat, Neufchâtel and Bienne, and extended also along the Orbe up stream from lake Neufchâtel to Entre-Roches, and down stream along the Thiele and the Aar as far as Solothurn. In the cantons of Berne, Fribourg, Solothurn, Neufchatel and Vaud, these occupied a superficies of about 190 square kilometers, which was either not under cultivation, or of which the meagre produce was frequently destroyed by inundations.

This state of things was the result of the irregular courses of the rivers, of the absence of any current in the Thiele between Nidau and Buren, and of the consequent elevation of the surface of the lakes. The Aar, swollen by the waters of the Sarine, covered (including its shingle banks) a large strip of land below Aarberg, and fell almost perpendicularly into the Thiele, near Meyenried. The latter river leaving lake Bienne with a lesser inclination, its waters became in consequence forced up stream against the natural current. This action of the Aar, the insufficiency and inequalities of the bed of the Thiele, and, above all, a sort of bar which existed above Brugg, had the effect of hindering the movement of the waters of lake Bienne, and therefore of those of lakes Neufchatel and Morat, and of considerably raising their level. Thus the neighboring country, saturated to a great distance from the river banks, was always maintained in a marshy state, and on the occasion of floods became a vast lake.

The object of the undertaking known as "The Regulation of the Waters of the Jura," is to improve the present condition of the rivers, particularly the Thiele and the Aar, by training their banks, and thus to lower the level in the lakes. The enterprise consists of—

1st. The derivation of the Aar from Aarberg on Lake Bienne by a canal from the Rappenfluh to Hagneck.

2d. The formation of a canal of sufficient capacity to convey the united volumes of the Aar and the Thiele, from their outlet on the lake, to a point below the junction of the two rivers.

3d. The regulation of the Upper Thiele and of the Lower Broye, so as to facilitate the flow of the water from lakes Neufchatel and Morat into lake Bienne.

To this must necessarily be added the opening of canals for the drainage of the marshes.

The main feature of the project, which is due to Colonel La Nicca, of Coire, is to constitute lake Bienne the regulator of the river Aar, to make it the receptacle of any gravel that may be brought down, and at the same time to neutralize the effect of the junction of this river with the Thiele at Meyenried.

The estimated cost of the works is as follows:

1. Canal from Aarberg to Hagneck..	£148,000
2. " Naden-Büren..............	196,000
3. " Upper Thiele..............	58,400
4. " Broye....................	29,600
5. Works between Büren and Solothurn........................	41,200
6. Administration, engineering and contingencies..................	86,800
	£560,000

The Swiss confederation contributes £200,000 to this amount. The remainder is furnished by subsidies from the Cantons interested, equal to the increased value of the land.

The Aarberg-Hagneck canal, which will carry the waters of the Aar to lake Bienne will be 5.15 miles long, with a fall of 1.4 in 1,000 to the Hagneck cutting, 4½ miles distant, and a fall of 3.75 in 1,000 for the remainder of its course. The canal will accommodate a maximum discharge of from 38,000 to 43,000 cubic feet per second. The width is 196 feet at the bottom for the greater part of the length, contracted to 131 feet in that part having a fall of 3.75 per thousand. The depth varies between 20 and 23 feet. The banks of the canal have a slope of 3 to 2, and are pitched with limestone, laid dry, and having a toe of the same material. This system of defense obtains for a length of 2.4 miles where the canal traverses compact travel. In the marshes, where the soil is turf on clay, the banks were first consolidated by a layer of gravel, and bundles of fascines, 2 feet 7 inches in diameter, were laid along the bottom before depositing the stone pitching. At a distance of 52 feet beyond each bank of the canal there is a secondary bank 20 feet wide at the top, which is elevated 24½ feet above the bottom of the canal, that is to say, out of reach, by 3 feet, of the highest known floods. These secondary embankments form at the same time occupation roads.

The most important work is the cutting through the Colline de Hagneck, which divides the marshes of lake Bienne. This cutting, the sides of which are in some parts nearly 100 feet high, will involve, for a distance of only 984 yards, 1,262,600 cubic yards of excavation in hard rocky marl. The total excavation for the Aarberg-Hagneck canal is 5,035,800 cubic yards. Except in the case of the Hagneck cutting, which had to be almost entirely made by artificial means, only a longitudinal trench (cunette), from 23 to 26 feet wide, cubing 2,082,800 yards, has been excavated. The erosive action of the water is counted upon to accomplish the remainder. To regulate this anticipated erosion, a weir has been constructed at the head of the canal near Aarberg, provided with sluices, allowing of the discharge of the desired volume of water. The result of the erosion in 1879 was very satisfactory. The water transported into lake Bienne 235,440 cubic yards, effecting a corresponding increase in the dimensions of the canal.

The Nidau-Buren outlet canal from lake Bienne is 7½ miles long, and has a fall of 1 in 5,000. The cross section is trapezoidal, the width at the bottom being 216½ feet, and the height ranging from 20 to 23 feet. The banks are inclined at 2 to 1. They are defended by dry stone pitching to the level of ordinary floods; above the slopes are wattled and grassed. This cut having considerable capacity, and the surrounding country being well elevated, there is no necessity for secondary banks as in the case of the Hagneck canal. The excavation amounts to 5,091,328 cubic yards, of which rather less than two-thirds have been removed by steam dredgers, and the remainder by hand labor and natural erosion, the latter action being only counted upon to the extent of 147,800 cubic yards.

The regulation of the Upper Thiele and of the Lower Broye consists only of training, deepening, and cleaning out the beds of those rivers, so as to allow lakes Neufchatel and Morat to participate in

the lowering of the level produced in lake Bienne by the construction of the Nidau-Buren and Hagneck canals.

The Upper Thiele has a length of $4\frac{1}{2}$ miles, and a uniform fall of 0.16 in 1,000. The width, as regulated, is $98\frac{1}{2}$ feet, the depth $19\frac{1}{2}$ feet, and the banks are sloped at 2 to 1.

The Lower Broye, between lakes Neufchatel and Morat, is 5.2 miles long, in which distance it falls 1 foot. The width at the bottom is $52\frac{1}{2}$ feet, the depth 16 feet 5 inches. At the head of the canals in the lakes moles are constructed.

These works, begun in 1869, are now (January 26, 1880) approaching completion. The Nidau-Buren canal is not yet quite finished, the last cut near Buren having still to be made. Notwithstanding this, it has already lowered the level of lake Bienne by 7.87 feet. The success of the works is therefore assured, and it only remains to complete them.

EXPLOSIVE AGENTS APPLIED TO INDUSTRIAL PURPOSES.

By Prof. ABEL, C. B., F. R. S., Assoc. Inst. C. E., &c.*

From "English Mechanic and World of Science."

The author pointed out that, since this subject had been brought by him before the Institution in 1872, the advantages of explosives more violent in character than gunpowder for many important industrial uses had become so widely known and extensively utilized, that the supremacy of gunpowder, as the only practically useful and economical blasting agent, had for some time been a thing of the past. The greatly superior results furnished by dynamite, gun-cotton, and other explosive agents of the same class, when applied to work in which their rending and shattering action was valuable, had led to the replacement of powder by them in many directions. It had also had the effect of rendering miners more critical in regard to the quality of blasting powder, a result which has operated beneficially, not only by requiring the bestowal of greater care upon the manufacture of blasting powder, but also by leading to improvements in the nature and form of powder. An improved blasting powder of Messrs. Curtis and Harvey was referred to as one illustration of this. An account was given of the advantages attending the employment of compressed powder, in the form of the charges first devised by Messrs. Davy and Watson, and manufactured by Messrs. John Hall & Son, which were rapidly coming into extensive use, and which presented unquestionable advantages over granular powder, on the score of convenience and comparative safety, as well as of greater efficiency. Other improvements in the application of gunpowder having been referred to, the author proceeded to examine into the progress which had been made in the production and application of preparations of gun-cotton and nitro-glycerine, observing that but few of the many proposed substitutes for gunpowder, to which he had alluded in 1872, had received any important applications.

The advantages attending the employment of wet gun-cotton were described, and the manner in which its detonation was brought about was examined; the theory of the development of detonation, as distinguished from explosion, and of its transmission, being incidentally discussed. Various important technical applications of wet gun-cotton, dynamite, &c., were referred to, as illustrating the utilization of the comparatively instantaneous character of detonation. It was pointed out that the safety, power, and comparative simplicity attending the application of wet gun-cotton to the larger operations for which violent explosives were valuable, had led to its adoption for submarine mines, torpedoes and military engineering operations generally. On the other hand, compressed gun-cotton, employed either wet or dry, was now only used to a limited extent as a blasting agent, chiefly in the form of preparations sold under names by which their actual nature was disguised. Thus, a variety of nitrated gun-cotton, converted

* Abstract of a paper, before the Institution of Civil Engineers.

into compressed charges, simillar to the original compressed pure and nitrated gun-cotton, was supplied to the miner under the name of Tonite. and its employment as an efficient blasting agent was gradually extending. An account was given of the rapid progress which had been made in the application of the nitro-glycerine and Kieselguhr mixture, called Dynamite, to the exclusion of other plastic nitro-glycerine preparations. The employment of dynamite upon a large scale was illustrated by reference to the stupendous operations connected with the destruction of the reef at Hell Gate, in East River, New York, when a total of 49,915 lbs, of dynamite and other nitro-glycerine preparations was exploded in one single operation. The objections to the employment of nitro-glycerine in the pure liquid state were pointed out. Reference was made to the tendency of dynamite to freeze, and the necessity for thawing it before use, as a prolific source of fatal accidents in connection with mines and quarries, owing chiefly to the recklessness of the men, and their disregard of caution and instructions. In the course of the paper, the author referred repeatedly, and in strong terms, to the mischievous and frequently disastrous effects of misleading statements with respect to the safety of particular explosive agents, such as the absence of noxious gases in connection with their use, &c., which had, from time to time, been published and circulated in mining districts by the manufacturers and venders, and which not only engendered false ideas of safety, but also encouraged the natural tendency to disregard precautions.

An account was next given of a new class of nitro-glycerine preparations, devised by Noble, of which the so-called blasting gelatine was the type, and which presented such decided advantages over dynamite in several directions, that they had already, to an important extent, supplanted it on the Continent, and promised to extend greatly the safe and efficient application of nitro-glycerine. In giving an account of the properties of blasting gelatine, and of certain difficulties which had to be overcome in its application, the author described a series of experiments he had made with a view of increasing the relative power, &c., of the more important explosive agents. Reference was also made to useful practical results which attended investigations on the transmission of detonation to considerable distances. The paper concluded with a review of the beneficial results in connection with the manufacture, transport, storage, and use of explosive agents, which had attended the judicious application of the measures included in the Explosive Act of 1875; and with these comments, on the one hand, on the necessity for increased activity on the part of local authorities in some directions, in connection with the Act, and, on the other hand, on the danger to the public and to commercial interests, resulting from the persistent refusal of railway authorities to facilitate the legitimate transport of explosives.

THE MANUFACTURE OF PRESSED FUEL.

By E. F. LOISEAU, Philadelphia.

From Transactions of the American Institute of Mining Engineers.

In a paper on the manufacture of artificial fuel, read at the Philadelphia meeting of February, 1878, I enumerated the difficulties which I had to overcome before succeeding in the mixing of coal-dust and clay, the compressing of the same mixture, and the water-proofing of the lumps. The drying of the lumps, after leaving the press, was the remaining difficulty, and it was expected that a plan devised by Dr. Charles M. Crosson, of Philadelphia, would enable us to dry the fuel as rapidly as it was moulded, and that a continuous production could in that way be obtained.

The company was reorganized. The works were purchased by the new company at an assignee's sale, and the oven was modified, according to Dr. Cresson's plan.

Anticipating a possible failure, I had prepared a plan by which I expected to be able to demonstrate that anthracite coal-dust, mixed with pitch, could be

manufactured with our present machinery slightly modified; so that, after all, if we were compelled to give up the attempt to make fuel for domestic use, there was a possibility of succeeding in the manufacture of a good steam-fuel.

The plan suggested by Dr. Cresson for drying the pressed lumps of coal-dust, cemented with clay, did not work as well as we expected. It enabled us to dry more fuel than we did before, but it could not be made to dry more than one-half of the lumps produced by the press. The plan was abandoned, and I was authorized to experiment with coal-dust and coal-tar pitch.

The cement which is used in Europe to conglomerate coal-dust is usually dry pitch, which is prepared by separating from the tar, at a temperature of 572° Fahrenheit, the volatile matters which it contains. Some manufacturers, however, employ crude tar, others, a rich tar, which has been cleared of 25 per cent. of its volatile substances, by heating it to 392° Fahrenheit. But with common tar very weak fuels are obtained, which do not burn well, and give out a strong smell and a great deal of smoke; it is also necessary to subject them to a baking process, in order to solidify them, and to eliminate the more volatile of the materials contained. This operation of course requires a special plant, the cost of which increases sensibly the price of manufacture, without counting the products which are lost, which have an industrial value. The crude coal-tar is also very inferior to the dry pitch, which can be broken and even pulverized when cold, and be thoroughly mixed with the coal dust. This produces briquettes that give off very little smell.

The mixing of the coal-dust and pitch is usually carried on in a vertical cylinder, into which the coal-dust and pitch are charged continuously and automatically. These substances are heated gradually in the cylinder or mixer by jets of steam which are discharged upon them from all sides; they are then triturated and amalgamated by a series of blades fixed on a vertical shaft. Arriving at the bottom of the cylinder, the materials are discharged in a pasty condition, through openings, from which they are placed or conveyed to the moulds.

In order to obtain a good lump from this paste, the pressure must be at least 3,000 lbs. per square inch, and in certain cases, with hard or lean coal, it is necessary to increase this by 50 per cent. This heavy pressure is required by the nature of the paste, in order to expel the water which it contains, and to bring it to a compact condition. In European mixers the steam injected into the materials escapes with difficulty and condenses rapidly, hence the moisture in the mixture, which is only expelled by strong pressure.

When steam is injected through perforations into the materials to be mixed it loses in reality its pressure, that is, the tendency to push asunder the sides of its containing vessel; but at the same time it produces a temperature corresponding to a considerable pressure. Steam gives up first its latent heat, and then, after suffering condensation, a portion of its free heat corresponding to the difference of temperature, and the mass thus becomes continually heated. This, however, requires time, and it occurred to me that if I could dry the coal-dust first, bring the same to a certain degree of heat, and mix it with coal-tar pitch in a molten state, I would obtain more rapidly a plastic mixture which could be moulded by the same rollers used previously to mould the mixture of coal-dust and clay.

I was well aware that my mixer was not the right apparatus to mix rapidly coal-dust and melted pitch, but I had seen at work a mixer invented by Mr. August Deitz, of Philadelphia, for the mixing of sand and asphaltum for paving purposes, and I had no doubt that it could be modified to answer my purpose.

Before obtaining the means to make the required alterations in the plant, I had to demonstrate the possibility of making the fuel in this way. I made the demonstration in a very primitive way. I hired two men engaged in the tar and gravel-roofing business, and had them melt the pitch in the yard and hoist it up in buckets, from which I dipped the pitch with a gallon measure, and emptied it into the mixer. A certain quantity of coal-dust previously heated, had before this been discharged into the mixer. In the bottom of the mixer I had placed a steam pipe, 1 inch in diameter, with perforations of $\frac{1}{8}$ inch, through which I injected steam into the materials until

they were brought to a plastic condition, when I gradually discharged them into the hopper of the press, and moulded the same without difficulty.

The moulding rollers are hollow, so as to enable us to warm them by steam. As I had no steam connections made, in order to prevent the adhesion of the materials to the rollers, the moulds were lubricated by means of two tin pans, filled with water, placed underneath each roller, and in which it revolved to a certain depth.

The lumps were very hard; the demonstration seemed to be conclusive; at least it appeared so to one of our stockholders, who offered to make the required alterations at his own risk if he was allowed to try a mixer which he had devised, and which, he thought, would answer my purpose as well as Dietz's mixer. The attempt was not a successful one, and as our means were nearly exhausted, I had but a poor chance of carrying out my ideas, when another stockholder came in who approved my plans, and offered to apply them, on certain terms and conditions, which were accepted by the company.

There is a rule attributed to Bacon which says: "Begin with observation, go on with experiments, and supported by both, try to find a law and a cause." I tried my best to apply that rule. The man who is experimenting, and wants to have absolute facts to work upon, is often made to doubt his own sagacity and capability, for he must often change his course of action by reasons of deductions drawn from experiments. It so happened with me. I had carefully planned with Mr. Dietz all the details of his mixing machine, in order to adapt it for our purpose. Still I had lost sight of one essential point, and that was to keep the materials, when mixed and brought to a plastic condition, in a hot condition in a close conveyer instead of an open one, as we have now. The pitch acquires its cementing properties from 170° to 212° Fahrenheit; below 170° it loses them. When exposed to the atmosphere, the mixture chills gradually, and when the pitch coating of the particles of coal is chilled it prevents the perfect adhesion of the particles under pressure. While the pressed lumps are still warm their surfaces are smooth, and the chilled particles apparently adhere, but when the lumps are cooled, the rubbing of one lump against another sets loose the chilled particles which accumulate and create dust again in the coal pockets in the carts, and in the cellars of the customers. This defect, however, can be easily remedied by replacing the open conveyer under the mixer by a closed one, and heating the moulding rollers with steam.

In Dietz's mixer are two horizontal shafts, to which are clamped a series of blades placed at opposite angles, and which make 35 revolutions in a minute. When the materials are mixed they are dropped into the conveyer underneath, through apertures in the bottom of the mixer, which are opened and closed by means of sliding doors operated by a lever. In this conveyer, the materials are also carried forward towards the hopper of the press by blades placed at the same angle on two horizontal shafts, but they make only 3½ revolutions per minute. With this mixer a quantity of materials, weighing a little over 1,000 lbs., is mixed and brought to a plastic condition, ready to be moulded, in the short space of 2½ minutes.

The coal and the pitch are both measured, and the proportions are 9 per cent. of pitch to 91 per cent. of coal-dust.

The moulding press is composed of two rollers geared together, on the periphery of which are milled out a series of semi-oval cavities, connected with one another, in order to facilitate the dropping of the lumps from the moulds on an endless belt placed underneath.

The efficacy of moulding rollers is not accidental or arbitrary, but is governed by certain rules which may be determined on mathematical principles, if not with perfect exactitude, at least with a tolerable degree of accuracy. Moulding rollers accomplish the compression of materials more by a squeezing or bruising action. They possess the great advantage of squeezing the materials so that the feed is only a short time between the rollers. This advantage is a very important one, and it will not be surprising if rollers, as a matter of fact, are destined hereafter to play a great part in the manufacture of artificial fuel.

If we follow the materials in their passage through two rotating rollers, we

find that they begin to adhere at a certain point, depending partly on the dimensions of the rollers and partly on the size of the lump. The particles of coal coated with pitch receive no pressure at the first point of contact from the face of the rollers, but from the drawing-in action of the two revolving rollers. The squeezing pressure which is thus exerted on the materials is produced entirely by the gear of the rollers, because, through the rotating motion, the plastic mixture is drawn into a gradually decreasing compass, and must be highly compressed and moulded. This reduction takes place regularly, both rollers possessing an equal speed. The speed being equal, the product leaves the rollers in the shape given by the moulds.

If the arrangemant of the compressing rollers is such that they may be approached to one another at will, by means of springs, the first result must be a diminution of the amount of power required, in comparison with the rollers with fixed pressure. The feeding of the materials will also be more regular, and the danger of breakages from pieces of iron, stones, etc., which are often found in the coal-dust, will be avoided, the springs yielding to allow the passage of these foreign substances through the rollers. It is to be regretted that our rollers are brought together by means of screws, instead of springs.

The great difficulty is the regulating of the feed. Rollers of large diameter draw in the feed better than those of a smaller diameter. The feed ought to enter under the regulating diaphragm, along the whole length of the rollers in an even stream; still this cannot always be the case, because the stream of materials is not even. A certain friction takes place between the particles of coal and pitch, because the proportion of pressure on the particles of the feed in the middle varies from the pressure exerted on the particles next the rollers, the latter being more compressed, and sometimes crushed. The entry of the feed should, therefore, not be forced, for in this case either a portion of it will pass through the rollers not sufficiently compressed, or a stronger pressure will have to be employed, which would alter the result desired, and would produce lumps sufficiently compact to resist rough handling without breaking, but not sufficiently porous to insure free combustion, without a blast or a strong draft.

The greatest difficulties experienced in the moulding of the coal and pitch were to obtain a regular feed of materials, and to prevent the accumulation of materials which solidified in the hopper of the press. These accumulations prevented also the regular delivery of the materials between the rollers. I succeeded in overcoming these difficulties by a very simple contrivance which works perfectly.

The coal-dust is dried and heated by two sets of four revolving drums, which answer well enough in dry weather, but when the coal is very wet we have some difficulty, and we are unable to dry and warm a quantity of coal sufficient to keep the mixer and the press running. This defect, however, can be easily remedied by increasing the size of the outlets for the escape of the moisture evaporated from the coal.

The defects of the present plant could have been corrected long ago, had I had the opportunity of carrying out my ideas. Through force of circumstances I was compelled to allow others to try plans of their own. The result was expensive, unsatisfactory, and unsuccessful experiments, the legitimate outgrowth of which was disappointment, disagreement, loss of time, of money, and of production. At last, however, I was allowed to have my own way, and the result was a success, although obtained with imperfect means.

The coal was placed in the market by myself, and I introduced it from the start for domestic use. It was supposed that the smoke and the strong smell of the burning pitch would be a serious objection to its use, but by careful instructions given to the customers, the inconvenience from the smell and smoke was hardly perceptible to those who followed instructions.

While experimenting with the fuel in different heating apparatus, I ascertained that when the lumps were but half consumed, if the poker was handled roughly, the particles of coal would disintegrate, and would fall, unconsumed, through the grate-bars into the ash-pan, seemingly increasing the quantity of ashes, but in reality losing the heating power of the

unconsumed coal. This was caused when the lumps were red-hot to a depth of about a quarter of an inch. Each lump would then become, so to say, a small retort. The pitch which held the particles of coal together, in the center of the lump, would gradually be drawn through the red-hot crust of the lump, and be consumed, and when the lump itself was partly burnt, and reduced to about one-third of its volume, there was not sufficient pitch left in the nucleus to keep the particles of coal together until they were consumed.

In order to remedy this very serious defect I mixed with the anthracite coal-dust about 8 per cent. of powdered bituminous coal. The result was a better fuel, which did not disintegrate, coked in the fire, and was almost entirely consumed, leaving but a small quantity of ashes, when compared with the fuel made from anthracite without the addition of bituminous coal.

This last fuel has found a ready market. It ignites readily, lasts as long as the ordinary anthracite coal, and it does not clinker. A good many of those who have tried it do not wish any other, and they send in new orders whenever their supply is exhausted.

It has been the main object of all inventors of machinery for the manufacture of artificial fuel to obtain a large production in lumps of a small size. It is easy to obtain a large production in lumps of a large size, and no better machine has yet been devised to obtain a large production than that described by Dr. Grinshaw in the *Journal of the Franklin Institute*, of September, 1879, and which is manufactured in France, by the Société Nouvelle des Forges et Chantiers de la Méditerranée. The production of a double machine, of the smallest size, does not exceed 96 tons in 24 hours, in lumps weighing very near 3 lbs. My press will manufacture in 1 hour, 13 tons of lumps weighing only 2½ ozs. each. These lumps require no drying or baking. They are conveyed to a screen in eight minutes, and that time is sufficient to cool the lumps. They are then ready for delivery.

The pressed fuel would be much improved if the coal-dust was previously washed, and in the erection of new works it will be essential to provide washing apparatus for that purpose. The difficulty now seems to be to secure a sufficient supply of coal-dust at the shipping points; and as there is a market for pea and dust, the coal companies do not feel inclined to dispose in our favor of the dust proper, so as to enable us to manufacture a fuel which would compete with their own coal. The successful manufacture of the pressed fuel, being however, a demonstrated fact, it will evidently be in the interest of the large companies to erect machinery to utilize the coal-dust, instead of piling it up around the mines. Whether the manufacture of the pressed fuel is carried on by us or by the coal companies, the community at large will be benefited by the utilization of coal-dust, which was considered, until recently, a worthless material.

I have struggled during twelve years to obtain this result. I persevered under the most trying circumstances, having to overcome financial as well as mechanical difficulties. I am satisfied now that very little remains to be accomplished in order to make the manufacture of pressed fuel from coal-dust one of the most important industries of Pennsylvania.

From a recent consideration of the relations betwen radiation of heat and temperature, Prof. Stefan, of Vienna, is led to substitute for Dulong and Petit's known law this other: *The quantity of heat lost by radiation is proportional to the fourth power of the absolute temperature.* Dividing by six the differences of the fourth powers of the absolute temperatures of thermometer and enceinte, one gets nearly the numbers of Dulong and Petit. The law they have given agrees better with these numbers, but the numbers given by Desain and Provostaye verify better the law of Stefan. Experimenting in air, even when very rarefied, one obtains a very complex result, since recent experiments prove that air has a conducting power which remains the same, whatever its density. Prof. Stefan utilizes experiments of cooling for calculation in absolute value of the heat radiated by a body. He concludes by deducing from Pouillet's experiments the temperature of the sun, which he estimates at 5580° C.

RAILWAY CURVES.

From "The Engineer."

On the 23rd of February a train of the London Metropolitan District Railway Company got off the rails at a short distance on the down side of the junction of the lines from Turnham-green and Acton to Richmond and Kew Bridge. The train consisted of a tank engine and eight coaches, all fitted with the Westinghouse non-automatic brake. The engine was running fire-box end first. No one was seriously hurt. The right trailing wheel apparently mounted the right rail a short distance from the junction crossing. The flange ran on top of the rail for twenty yards, and then the wheel dropped outside it, smashing the chairs. One rail was broken, and five others injured. General Hutchinson, reporting on this accident to the Board of Trade, states that the line was in good order. The driver of the engine said that he was running at about twenty miles an hour when his engine left the rails; but his speed was probably somewhat greater. All the carriages followed the engine save the last. It is worth notice that as soon as the engine got off the track, the driver applied the Westinghouse brake without difficulty; but the fireman failed to put on the screw brake, as its mechanism was jammed. There is nothing remarkable about the accident itself; but the cause assigned for it by General Hutchinson deserves attention. "When I visited the scene of this accident," he writes, "there was a slight trace visible of the track of a wheel along the top of the 6 ft. rail—the high rail—of the curve of about $33\frac{1}{2}$ chains radius, round which the train was running when the engine left the rails; and from the description given by the engineer of the District Railway, who was on the spot about an hour after the accident happened, this track was at the time distinctly visible from opposite the down end of the check rail of the crossing to within about 2 ft. of the first broken chairs, a distance of about 21 yards. It is therefore tolerably clear that the right front wheel of the engine mounted the right or high rail of the curve directly after the left wheel had passed beyond the check rail of the crossing, *and that its doing so was due to the want of sufficient super-elevation in the high rail to meet the speed at which the engine was traveling.* If this super-elevation amounted, as it is said to have done, to about $1\frac{1}{2}$ inches at the crossing, it should have been sufficient for a speed of thirty miles an hour; and as it is not probable that the speed exceeded—even if it reached—this amount, the engine being only 150 yards from where it had to stop at Gunnersbury station, the cause of the accident was probably due to a deficiency of super-elevation in the high rail, owing, most likely, to the sleepers having sunk from the heavy rain which had fallen shortly before the accident. As it is impossible, on account of the junction crossing, to give the proper amount of super-elevation—$2\frac{1}{4}$ inches instead of $1\frac{1}{2}$ inches—round this curve near the crossing, it is most desirable that the check rail should be extended for some distance on each side of the crossing." There is, we think, reason to dissent from the conclusion which we have printed in italics. What that reason is we propose to set forth here.

General Hutchinson is apparently unaware of the fact that many engineers, both in this country and on the Continent, hold that the raising of the outer rail on a curve is a complete mistake; that it can do no good, and may do harm; and that they act on this principle and lay their curves without super-elevation. Again, many curves which have been originally laid with a high outer rail, have in process of time been permitted to lose their super-elevation; and it will not, indeed, be too much to say that not one curve in ten has the amount of cant dictated by theory. As the formulæ for calculating the amount of super-elevation of the outside rail on a curve are not very generally known, it may be convenient to give them here. According to the first it is assumed that on the 4 ft. $8\frac{1}{2}$ inch gauge no curve of a

greater radius than 1400 ft. requires the outer rail to be raised. For sharper curves the rule runs—subtract the radius of the curve from 1400 and divide the remainder by the radius of the curve and by 1400; multiply the quotient by the width between the rails, by the square of the velocity in miles per hour, and by .782; the product is the height in inches which the outer rail must be raised. This is the formula given by Mr. Henry Law, and was, we believe, that used by Brunel; a different constant from 1400 being adopted, however, because of the width of the Great Western gauge. Pambour gives the following formula: Let R=the radius of the curve; R′= radius of the curve which the train would describe in consequence of the centrifugal force and the inclination of the tire of the wheels; e=the gauge; g=the force of gravity; V=velocity; and x, super-elevation. Then

$$x = \frac{eV^2}{g}\left(\frac{1}{R} - \frac{1}{R'}\right) \text{ and } R' = \frac{den}{4\triangle},$$

where d=outer diameter of wheels, $\triangle$=their deviation, and $\frac{1}{n}$=the inclination of the tire. Rankine's rule is much simpler than either of the foregoing. He divides the requisite cant into two parts, one required to overcome centrifugal force, the other to resist the tendency to leave the rails caused by the circumstance that the wheels, although compelled to revolve at the same velocity, have to traverse different distances in the same time. The cant for centrifugal force=gauge$\times\frac{V^2}{15r}$ where V is the speed of the train in feet per second, and r the radius of the curve in feet. The additional cant for slip of wheels is, in inches, $=7200\div$ radius in feet, for the normal gauge.

It will be seen at a glance that, according to the first of these rules, no super-elevation whatever is required on a curve of 33½ chains—that in question. It is assumed, as we have said, that at no speed up to sixty miles an hour can any super-elevation be required. Pambour's rule cannot be applied unless the inclination of the tires is known. General Hutchinson does not allude to this factor. In our opinion the want of super-elevation on such a curve had nothing to do with the engine getting off the rails, the cause for which must be sought in another direction. The engine, a bogie tank locomotive, weighs 45 tons. The bogie is of the four wheel Bissel type, and carries 10 tons 7 cwt The driving wheels are loaded with 17 tons 15 cwt., and the trailing wheels with 17 tons 2 cwt. These are very heavy loads, and well calculated to test the stability of any road. Now, it is one of the great advantages of the bogie that its leading wheels, carrying a comparatively light load, quietly compress and settle a bad road for the heavy loads which follow it. But in the case under consideration, the engine was running with the bogie last, and a weight of 17 tons was thus brought suddenly to bear on the rail. Mr. Collis, inspector of permanent way, in his evidence stated that the sleepers had been "pumping." That is to say, they worked on the ballast, which was saturated with water, and made holes for themselves in which water and mud were churned as the trains passed. It will be remembered that a very severe frost had not long departed at the time of the accident. All the facts point, we think, to a weak spot in the road giving way under the tread of a heavy engine as the cause of the disaster. The engine lurched and left the rails. The station-master at Gunnersbury actually saw the engine getting off the track, and he states that it first "gave a lurch toward the 6 ft." It is worth notice that the plates of the left hand front spring—as the engine was running—were all knocked out of the buckle, but only two—the bottom plate and the third from the bottom—were broken. It is just possible that the breaking of the spring caused the accident. In any case it seems to be clear that General Hutchinson's explanation of the occurrence is not the true one.

If we come to examine the theory involved in the raising of an outer rail on a curve, it will be seen that it involves either a total fallacy, or that a practical difficulty stands in the way of its application. Taking the last proposition first, we may prove it by pointing out that as the amount of super-elevation depends on the square of the speed at which a train is traveling, what is right for one

velocity must be wrong for all others, and accordingly instances are not wanting in which trains have actually slipped off a curve on the inside when running slowly round it because of the excessive super-elevation of the outer rail. Again, Pambour's formula cannot be used, as we have pointed out, unless the inclination of the tire is known; but in the present day the practice of coning tires has become almost extinct—that is to say, the tires are very nearly cylindrical as they leave the lathe, and in engine wheels, at all events, they very soon lose the taper altogether, a shallow groove taking its place; but if cylindrical wheels are used, it will be found that the tendency of the wheels to run in a straight line, resulting from the circumstance that they must both revolve at the same velocity, may be a much more powerful factor than centrifugal force in any attempt which the engine or carriages may make to leave the rail. The centrifugal force of a train is to its weight as $\frac{V^2}{32r}$: 1, v being the velocity in feet per second, and r the radius of the curve in feet. A locomotive engine weighing 45 tons and running at sixty miles an hour round a curve of 880 ft. or 13.3 chains radius, would have a centrifugal force of nearly 13 tons; but such a velocity is never attempted on such a curve. We may reduce the virtual velocity by one-half, either by dividing the radius or halving the actual speed of the train. In either case, as the centrifugal force varying as the square of the velocity, the force tending to carry the engine off the rails would be one-fourth of this, about 3 tons, little more than one-fifteenth of the weight of the engine; but one of each pair of wheels must be made to slip before the engine can get round the curve at all, and the resistance to slipping will equal at least one-sixth of the insistant weight on the engine. A very simple calculation, which we need not give here, will show that under some circumstances the tendency of the engine to leave the rails, because the wheels cannot revolve independently, and the axles do not radiate to the curve, is greater than the centrifugal force. Of course this has to be added to the latter, not deducted from it. It is not to be used as an argument against raising the outer rail, but in favor of the practice; but it is never taken into account at all in the formulæ we have quoted from Pambour and Law—though it is used by Rankine. In fact, both are based on the assumption that the coning of the wheels will approximately compensate for the difference between the spaces passed over in the same times by the two wheels keyed on a rigid axle, and so leave nothing but centrifugal force to be dealt with. But no such compensation really takes place, as we have pointed out, and thus it is found that the conditions under which alone the rules we have quoted will apply accurately cannot be, or at all events are not, secured in practice. It is not remarkable, therefore, that in the present day when an outer rail is raised at all, its super-elevation is fixed by a kind of rule-of-thumb table supplied to the ganger or foreman of platelayers.

Apart, however, from all questions of minute accuracy is one far more to the purpose—does the raising of an outer rail really compensate for the influence of centrifugal force? It must be clearly understood that the outer rail is *not* raised to prevent the carriages from being overturned, as is very commonly believed, but simply to keep the outer flanges from rubbing hard against, or possibly mounting, the outer rail. The theory is that a pair of wheels can traverse sideways on a pair of level rails without offering any resistance, save that caused by the adhesion of the wheels and the rails. Thus, a pair of wheels carrying, say, 12 tons, could be moved endways or in the direction of the length of the axle by a force of, say, 2 tons; and this would be true, no matter what the inclination of the tires, because as much as one wheel rose, as the flange approached the rail, the other would fall; and so the position of the center of gravity, vertically, would remain unchanged. If, however, one rail be raised, then, in order to move the wheels, a force must be applied sufficient not only to overcome the adhesion of the wheels to the rails, but enough to lift the weight as well. Now, according to Law, the proper elevation of the outer rail on a fifteen-chain curve for sixty miles an hour is 4 in., that is, very nearly one-fourteenth of the distance between the rails. Thus,

the resistance to lateral motion due to gravity in this case, will be equal to one-fourteenth of the load, or for a load of 12 tons to little more than three-fourths of a ton. It would appear that the addition of this resistance to that already offered by the adhesion of the wheels is quite unnecessary, and can in fact do no good. Practice goes to prove this proposition; in the first place, because the system of raising the outer rail has been given up, to a great extent, without causing any bad consequences; and because, in the second place, raising the outer rail does not prevent the flanges from grinding against it on curves, this grinding being induced by causes with which the super-elevation of the outer rail apparently cannot deal.

SUGGESTIONS FOR DEALING WITH THE SEWAGE OF LONDON.

By MAJOR-GEN. H. Y. D. SCOTT, C. B., F. R. S.

From the "Journal of the Society of Arts."

In compliance with a resolution passed by the Metropolitan Board of Works, in November, 1857, a report was presented to them in the following year, by Messrs. Bidder, Hawksley & Bazalgette, on the "Main Drainage of the Metropolis." In this report, the Metropolitan Board were told:

"The referees say (Report, p. 9): 'It would also appear that the black mud from the sewage contains a considerable quantity of organic matter, which is most deleterious; an immense mass of this fœtid mud has accumulated in the bed and on the banks of the river, and it is continually supplying to the water large amounts of soluble matter in a state of putrescence, and contaminating the atmosphere with most offensive emanations. It is probable that the unhealthy condition of many towns on the sea coast is caused by deposits from the sewers by mud of this character.'

"And Dr. Hofmann and Mr. Witt, at p. 7 of their report, employ the following forcible expressions:—'We cannot but emphatically insist upon it—that the formation of this mud-deposit in the river appears to us by far the most serious evil which results from the discharge of the London sewage into the river. We cannot too strongly urge this point upon public attention.' In these conclusions (say Messrs. Bidder, Hawksley, and Bazalgette) we entirely agree, and although we are not disposed to think that the whole of this noisome mud results from the deposition of sewage matter, yet we are satisfied that a real and increasing evil has its origin in this source, and that this evil has already attained such proportions as to render it essential to the well-being of the metropolis that means should be taken for its immediate and permanent abatement.

"Any person who examines the state of the Thames, especially within the tidal reaches, whether above or below the metropolis, will be satisfied that the periodical withdrawal of the water of the river from the muddy surface of its bed is, in the hot weather of summer, invariably succeeded by disagreeable emanations, only too plainly indicative of the decomposition of animal and vegetable organisms."

The main drainage of the metropolis was eventually carried out in accordance with the recommendations of this report, so far as concerned carrying all the sewage to the present main outfalls. Since 1866 these outfalls have been in full operation, and have daily discharged the raw sewage of the metropolis between the towns of Woolwich and Erith, the results being precisely such as might have been expected from the above evidence. It is true that, inasmuch as the sewage is now discharged into a larger body of water than formerly, and at a point more distant from the great center of population, the evil effects are considerably mitigated, but they are the same in kind, and in 1877, Captain Calver reported to the Conservators of the Thames, by whom he had been commissioned to examine into the question, that the Metropolitan Board of Works ought

"to be called upon at once to dredge away those portions of the accreted matter which interfere with the convenience of navigation;" and he concluded his report with an expression of his "hope that the sanitary and economical difficulties may ere long, be solved, so that the noble metropolitan river committed to their (the Conservators') care may be freed from a drawback which is impairing its convenience and usefulness, and which must continue to do so at an increasing rate without an effective remedy is speedily applied."

The Metropolitan Board, on the other hand, contend that the discharge of the raw sewage is neither damaging the river navigation nor the health of the dwellers on its banks, and Sir Joseph Bazalgette maintained at the Institution of Civil Engineers:—

"That the bed of the river had improved of late; that the improvement was not due to systematic dredging; and that the mud banks were not formed by sewage."

Without entering further into the arguments adduced on either side, it is necessary, for the basis of my reasonings, to point out clearly that the three engineers nominated by the Metropolitan Board, to report to them on the main drainage of London, laid before them the following conclusions, which, indeed, having quoted the above-recited evidence, it would have been difficult not to have arrived at, viz.:—"That mud, containing much organic matter, derived, in great measure, from the sewage discharged above low water mark, is deposited on the foreshores of the river, and there putrefies;" and, "That the condition of the stagnant mud is injurious to health." (Report, p. 95.) Further argument is not necessary to show that what was true with respect to the admission of sewage into the river at several points, situated in and about London, must be true, though to a minor degree certainly, when the sewage is thrown into the Thames by two outfalls between Woolwich and Erith. It is impossible to believe that the organic matter of the sewage will wholly lose either its tendency to deposit on the bed of the river, or to putrefy when there, whatever changes may be made in the situation of the outfalls.

The liquid and richest portion of the sewage of the 3,500,000 souls in London, who contribute to the contamination of the Thames, is, in the opinion of all chemists, after its admixture with water, irrecoverable, unless it can be utilized by irrigation; while the solid suspended matters—which all the Royal Commissions on sewage disposal have, one after the other, declared to be the most injurious part of sewage impurities—if they could be recovered, and be made into portable manure, would each year be worth more than a quarter of a million of money.

That it is impossible to accomplish this object to a large extent, I hope to be able to prove to you in spite of all that has been said and written concerning the worthlessness of sewage manures. In this matter, as in many others, English people have rushed into extremes. From unbounded and childish trust in the wildest schemes, they have now ceased to put faith in any

The object of this paper is, then, to show that if the investigations and analyses of the most eminent living chemists are correct, it follows that sufficient value can be recovered from the suspended matters of metropolitan sewage, obtained by simple subsidence, and unmixed with bulky precipitating materials, to meet all the expenses of keeping such an offensive and injurious matter as solid sewage out of the Thames.

The first point for consideration will be the composition of the suspended matters of sewage, being those which I propose to utilize, and which, however deposited, whether by simple subsidence, or precipitation by chemicals, are termed "sludge."

These matters consist, 1st, of the *debris* of human fæces, mingled with the solid dejections of animals washed from stables, court-yards, and the streets, and also of the *debris* of animal and vegetable refuse from our kitchens; and 2nd, of the mud and sand scoured from the streets. The first-named constituents possess nearly the whole of the manurial value, and it is important for our inquiry to ascertain of what fertilizing elements the fæces of a population consists. By ascertaining the proportion of these elements to the organic matter associated with them, we can arrive at the value of such refuse matters as consist partly of fæcal and partly of other organic substances.

The researches of Lehmann, Wolf,

Röderer, and Eichhorn, from which tabular extracts are given by the Rivers' Pollution Commissioners (1st Report, p. 27), enable us to arrive at the composition of fæces with great certainty; and the analyses and investigations of Professor Way, carried on at Rugby, under the auspices of the Royal Commissioners on the disposal of Sewage, will, when considered in the light given by the above extracts, assist us materially in arriving at a conclusion respecting the valuable elements derived from other sources. With respect to the second class or the detritus, as this is worse than useless, it may be rightly designated as a "profligate associate," deserving no other consideration than how to lessen it, since it still further degrades the value of a manure already too poor. In Paris, where they are rapidly carrying out a system which allows the solid fæcal matters to be recovered without admixture with detritus, the contractor can afford to collect them for the fertilizing elements which they contain; but we must deal with the matters as they arrive at the outfall, in which state the worthless ingredients greatly exceed in amount those which have a value.

The tables of Röderer and Eichhorn, above alluded to, give the annual weight of the fæces of a mixed population of 100,000 persons as 64,937 cwt., consisting of 957 cwt. of nitrogen, and 1,347 cwt. of phosphates, which, reckoning the phosphate as tribasic calcic phosphate, will amount to 622 cwt. of phosphoric acid, and this assumption we may make without important error.

From these figures it would appear that the nitrogen is to the total weight of the fæces as 1 is to 67.8, or deducting the water, which constitutes three-fourths of the total weight of the fæces, the nitrogen is to the organic matter as 1 to 16.9; and the phosphoric acid is to the organic matter as 1 to 26.

At page 29 of the Third Report of the Commissioners on the distribution of sewage, are given the results of Professor Way's experiments at Rugby, extending over two and a half years, samples being taken every two hours out of the twenty-four. This series was divided into three periods, and subsequently two sets of samples were collected for five days a year later, and the ratio of the nitrogen to the organic matter, other organic refuse being now mixed with the fæces, will be found to be on the average as 1 of nitrogen to about 15 parts of organic matter.

From these results we can conclude, without much danger of error, that the sludge of the Rugby sewage, omitting all mineral detritus, is at least as rich as fæces in that most important element, nitrogen. As respects phosphoric acid, though it was otherwise at Rugby, no great difference exists in the case of London sludge, as compared with fæces, as will presently appear. From the above different observations and sets of samples, the ratio of the phosphoric acid to the organic matter was for the Rugby sludge as 1 to 31.6.

At page 47 of the Report on Metropolitan Drainage by Hofmann and Witt, an analysis is given of the insoluble as well as of the soluble portions of the sewage from Dorset-square, London, from which it appeared that the amounts of the above mentioned substances per gallon were as 1 of nitrogen to 10 of organic matter; and 1 of phosphoric acid to 14.2 of organic matter.

Again, from some samples of sludge deposits, collected hourly throughout the day at Ealing, which were very carefully analyized by Mr. Shepheard, F.C.S., in the laboratory of Dr. Frankland, the following results were obtained as the ratio of the nitrogen and phosphoric acid to the organic matter:

$$\frac{\text{Nitrogen}}{\text{Organic matter}}=\frac{1}{26.5}\qquad\frac{\text{Phosphoric acid}}{\text{Organic matter}}=\frac{1}{27.7}$$

The foregoing sets of experiments were made under such different conditions as to time and place and length of trials, that it is somewhat difficult to arrive at a fair mean. But an unobjectionable course, perhaps, will be to compare the highest and lowest results with the composition of fæces, as given by Röderer & Eichhorn, and take care to err, if we do err, on the side opposed to that which we are endeavoring to prove. These results are as follows:

	Highest result.	Lowest result.	Mean result.	Fæces.
$\frac{\text{Nitrogen}}{\text{Organic matter}}$ =	$\frac{1}{10}$	$\frac{1}{26.5}$	$\frac{1}{18.2}$	$\frac{1}{16.8}$
$\frac{\text{Phosphoric acid}}{\text{Organic matter}}$ =	$\frac{1}{14.2}$	$\frac{1}{31.6}$	$\frac{1}{22.9}$	$\frac{1}{26}$

Dr. Letheby, after carefully comparing the results of his own analyses, which were very numerous, with those of Drs. Way and Voelcker, and the figures adopted by Drs. Hofmann and Witt in their investigations, came to the conclusion that in the suspended matters of town sewage the ratio of the nitrogen and the phosphoric acid to the organic matter, was—

	From excreta.	From all other refuse.	From all sources.
$\frac{\text{Nitrogen}}{\text{Organic matter}} =$	$\frac{1}{15.5}$	$\frac{1}{36.6}$	$\frac{1}{20.6}$
$\frac{\text{Phosphoric acid}}{\text{Organic matter}} =$	$\frac{1}{16.9}$	$\frac{1}{18.7}$	$\frac{1}{17.96}$

It would appear, from a consideration of the foregoing results, that, in different towns, owing to the influence, chiefly, of other refuse than excreta, the ratio of the fertilizing elements to the organic matters may vary considerably; but, looking to the results of the examinations of the Dorset-square sewage by Dr. Way, we may feel some confidence that the chief fertilizing elements in the London sewage sludge will be under, rather than over, stated, if we assume that—

$$\frac{\text{Nitrogen}}{\text{Organic matter}} = \frac{1}{20} \qquad \frac{\text{Phosphoric acid}}{\text{Organic matter}} = \frac{1}{25}$$

The potash is the third and only remaining valuable element found in sewage sludge, and, according to Letheby, it owes its presence entirely to the fæcal matters. Any potash present with granite detritus is not in a condition immediately available for plant life, and cannot, therefore, be reckoned as of any manurial value. From Way's analysis, the proportion of potash to organic matter in fæces is as 1 to 18.6, but, from the analyses made by Dr. Voelcker, of the precipitated sludges of four towns named in Messrs. Rawlinson & Read's report, viz: Bolton-le-Moors, Bradford, Coventry, and Leeds, all of which, excepting Coventry, are deficient in fæces, the mean ratio is—

$$\frac{\text{Potash}}{\text{Organic matter}} = \frac{1}{51}$$

and from Dr. Way's analysis of the sludge of the Dorset-square sewer, already referred to, the potash appears to have equaled the $\frac{1}{56}$ part of the organic matter; I therefore adopt the $\frac{1}{56}$ as the proportion of potash likely to be found in the metropolitan sludge. Recapitulating the results we have arrived at, we may assume then that with each part of the three fertilizers—nitrogen, phosphoric acid, and potash—there will be associated in the sewage sludge of London 20 parts, 25 parts, and 56 parts respectively, of organic matter.

We have now to see to what extent these results will be influenced by admixture with detritus—the third, and by far the most variable, as well as the most worthless, component of sludge. The detritus should on every account be excluded, as far as possible, from the sewers. At present, however, I shall limit my observations to the separation of the detritus from the more valuable organic matters when the sewage reaches the outfalls, with a view to its exclusion from the manure to be prepared from the sludge, as well as to its exclusion from the river. That this can be effected to a considerable extent will be evident from the valuable report of Captain Calver, from which I have already quoted. Captain Calver gives, at page 16 of his report, two analyses by Professor Williamson; the first stating the amount in grains per gallon of the suspended and dissolved constituents of the sewage as it issued from the northern outfall sewer; the second—the amount, similarly stated, of the suspended and dissolved constituents of the sewage as it flowed from within the apron of the reservoir, into the Thames two hours after high water, that is to say, after the velocity of the current was diminished and the sewage had deposited the heavier particles.

Contents in Grains per Gallon.

Suspended Matters.	No. 1. One hour before low water.	No. 2. Two hours after high water
Organic matters........	37.24	104.97
Sand......	44.10	23.52
Iron, alumina, carbonate of lime, &c..........	26.67	23.01
Total suspended matters	108.01	151.50

For No. 1 analysis the $\frac{\text{organic matters}}{\text{mineral}} = \frac{1}{1.9}$ and

For No. 2 " " $= \frac{2.25}{1}$

The suspended matters in the sewage, when issuing from the sewer into the reservoir, contained only 34 per cent. of organic matter, and as the sewage issued from the reservoir into the river, the suspended matters contained, at one period of their flow, about 70 per cent. of organic matter. To this extent, therefore, it is manifestly possible to effect a separation of the sand from the more valuable constituents of the sewage. We require only, for the purpose of this separation, an additional reservoir for the subsidence of the lighter organic matters, after the heaviest mineral particles have been deposited in the existing reservoir.

From this second reservoir, in which I would propose that the sewage should have a period of quiescence, we might expect the sludge to show the following analysis:

Organic matter (without nitrogen)	66.50
Nitrogen	3.50
Phosphoric acid 2.80=tribasic phosphate of lime	6.07
Potash	1.25
Sand and inert mineral matter	22.68
	100.00

a result which corresponds very nearly with the composition of the sludge at Ealing, analyzed by Mr. Shepheard, already referred to. It is a little richer in nitrogen, however, as was to have been expected from the analysis of London sludge by Professor Way.

I should here remark that different analyses of London sewage vary considerably in the proportions of the mineral and organic matters. Letheby determined that the—

$$\frac{\text{Organic matter}}{\text{Mineral matter}} = \frac{1}{1.36}$$

It would appear, however, from the analyses of London sewage given in the Rivers Pollution Commissioners' first report, to be—

$$\frac{\text{Organic matter}}{\text{Mineral matter}} = \frac{1}{1.55}$$

and Professor Williamson's analysis, from Captain Calver's report, gives—

$$\frac{\text{Organic matter}}{\text{Mineral matter}} = \frac{1}{1.9}$$

As the detritus imparts no value to the sludge, but has a contrary effect, we shall err on the safe side if we assume as Captain Calver states, that—

$$\frac{\text{Organic matter}}{\text{Mineral matter}} = \frac{1}{2}$$

And we see that by a period of repose we may easily bring the ratio to—

$$\frac{\text{Organic matter}}{\text{Mineral matter}} = \frac{2}{1}$$

We must next inquire into the values of the fertilizing ingredients of the sludge, viz., the nitrogen, calcic phosphate, and potash.

It is usual with agricultural chemists to consider the nitrogen, associated with organic matter which freely decomposes, to be as valuable as nitrogen in the form of salts of ammonia; for instance, in guano, of which about one half the nitrogen exists in the form of ammoniacal salts, and the other half as nitrogenized organic matter, which has still to pass into the form of ammonia before it becomes operative on vegetation, this latter half is considered as valuable as the first, owing to the quickness with which it changes into the ammoniacal condition. In night soil, the rapidity of its decomposition also raises its nitrogen to the rank of nitrogen in the form of salts of ammonia; but when fæcal matters have been washed with water, so that they become less liable to putrefaction, and are mixed with other nitrogenous compounds, such as hair, vegetable *débris*, &c., which do not so readily decompose, some deduction from the value of the nitrogen should be made. Accordingly, Dr. Voelcker, when analyizing different samples of sewage manures for the report on sewage disposal, by Messrs. Rawlinson & Read, whilst assigning to the nitrogen the same value as if it existed as ready formed ammonia, stated expressly that he did so in order to avoid the charge of having put too low a value upon these manures; and in speaking on the same subject at the Institution of Civil Engineers, on the 28th of March, 1876, the price of ready-formed ammonia being at that time 16s. per unit, he said that 15s. per unit would be too high for the value of nitrogen, reckoned as ammonia, before its conversion into such. Consequently, Dr. Voelcker estimated that the calculated value of nitrogen, not already converted into ammonia, should be less than the value of ready formed ammonia by at least 6½ per cent. on the value of the latter. Probably,

therefore, we may safely calculate nitrogen, before conversion, as being worth 10 per cent. less than the market value of nitrogen in ammoniacal salts, such as sulphate of ammonia. The market price of this substance is at present 20s. per unit. I will, therefore, take the nitrogen at 18s. per unit. Concerning the value of phosphoric acid, which varies considerably as it exists, in a condition either of insolubility or of solubility, I must speak at some length; this material being one I propose to add to the sludge, as I shall hereafter explain, in such a manner as to convert this ingredient into precipitated phosphate of lime. Any error in its assumed value is, therefore, of especial importance.

Dr. Voelcker made a very exhaustive series of experiments for the Royal Agricultural Society on the salubrity of phosphatic materials, and he drew the following conclusions amongst others from his investigations. "Pure and dried phosphate of lime is sparingly soluble in water."

"In a moist state and in the voluminous condition in which it is obtained by precipitation from its solution, it is about four times as soluble in water as it is after it has been dried and heated."

"The earthy phosphates in Peruvian and phosphatic guanos, still containing a good deal of organic matter, or salts of ammonia, are sufficiently soluble in water to be readily appropriated by plants." And in a letter to me, Dr. Voelcker writes; "The absence of acidity in the manure is an advantage when it is applied to land deficient in lime. There are many such soils, and on these phosphoric acid, in the shape of precipitated phosphates, produces a better effect upon vegetation than phosphoric acid in the shape of an acid soluble superphosphate for unless the acid is rapidly neutralized by the alkaline elements (notably, the lime in the soil), and precipitated in the soil, it cannot benefit the crop to which the superphosphate is applied. On the other hand, if there is a sufficient amount of lime or of other basic constituents in the land to precipitate the phosphate in superphosphate, I consider it better, as regards the distribution of phosphoric acid in the land, to apply the manure in the shape of superphosphate than in the form of precipitated phosphate. It is, moreover, impossible to distinguish by chemical means, with any degree of accuracy, precipitated from ordinary phosphate of lime, and, in consequence, purchasers of manure will regard a guaranteed percentage of phosphates, actually soluble in water, with more favor than a guaranteed percentage of insoluble phosphates which may be present in a manure, partly as precipitated, and partly as ordinary insoluble phosphates;" and he suggests that a firm should sell manure, in which precipitated phosphates occur in plenty, "without any analytical guarantee, but on an established reputation for introducing into the manure precipitated phosphates only," and thus "give the public a reasonable guarantee they are really present in a precipitated form."

It would appear, then, that Dr. Voelcker looks upon precipitated phosphates as being intrinsically little inferior, and for some soils, superior to acid superphosphate, and as far as agriculture is concerned, the precipitated might be substituted for the perfectly soluble phosphate, without appreciable loss of manurial efficacy. The difficulty lies in the analysis, and is essentially a technical one, which it is to be hoped chemists will find the way of overcoming, as precipitated phosphates are brought more into use. Indeed, there are some who are already commencing to listen to the complaints raised against such unjust valuations of manure as are given by chemists in respect of precipitated phosphates, and Mr. Sibson, in his useful little work on artificial manures, says: "The identification of this form of phosphate (reduced or precipitated phosphate), being thus often a matter of importance, I now give its approximate amount when so required; at the same time I should plainly state that I consider it distinct from soluble phosphate;" and he gives the following scale of prices per unit, for fertilizers for 1878, such prices "being intended to apply to the purchase of manures under the circumstances usually prevailing in agricultural districts, when they are supplied in bags, carriage paid, and credit given. When bought in quantities, in bulk, for ready money, or fetched from the works, of course a lower scale would apply:"

Price per unit for—	s.	d.
Soluble phosphate	4	6
Ditto in mineral superphosphates	4	0
Precipitated phosphates	3	6
Insoluble phosphate (bone or guano)	2	6
Insoluble mineral phosphate, up to 7 per cent	1	0
Potash sulphate	3	6
Ammonia	20	0

There can be no doubt that precipitated phosphates mingled with the decomposing matters of sludge, a very putrescible substance, are, under conditions, highly favorable to solubility. As may be seen, from the investigations of Dr. Voelcker, ammoniacal salts materially increase the solubility of phosphates. And since, as is well known to chemists, phosphate of lime is easily soluble in carbonic acid, and both ammonia and carbonic acid result from the decomposition of the organic substances, there seems no reason for giving to precipitated phosphates in sludge manures a lower value than that assigned to them in Mr. Sibson's table, under the terms of sale to which that table is intended to apply. To the phosphates naturally accompanying the organic matters which the sludge contains, we should assign the same value as in the case of bone or guano.

Let us now investigate the cost of producing precipitated phosphate of lime, intermingled with sludge. I should premise that, as our object is not the preparation of a dry superphosphate, such as is manufactured for the market, a much freer supply of water is admissible than in the ordinary process of manufacture, where a dry powdery condition is essential in the finished product; a condition, moreover, somewhat difficult to obtain. The use of plenty of water much facilitates the process of solution, by enabling the acid to act more freely and perfectly on the mineral. It also does away, in great measure, with the noxious fumes evolved in ordinary superphosphate making, so that the process can be carried on without any extraordinary precautions. The mixing may be effected in strong wooden troughs, about 9 feet by 4 feet by 3 feet, pitched inside, and the dilute acid and mineral, finely powdered, should be stirred together for some minutes, until all action ceases. For one charge of a vessel such as the above, there will be required about 20 cwt. of Cambridge coprolites and 17 cwt. of brown sulphuric acid; or if mineral phosphates, with less carbonate of lime than Cambridge coprolites, be used, a little less acid is needed. Enough water should be used in order to leave the mixture in a more than semi-fluid condition, in a state in fact which admits of being readily mingled with the sludge; this sludge must have previously had mixed with it a sufficiency of milk of lime to leave the mixture alkaline after the application of the phosphoric acid.

The cost of bringing the phosphoric acid into solution, and of adding the lime, will be as follows. I obtain the proportions, excepting for the lime and the water, from Mr. Sibson's work on artificial manures, from which I have also taken the above account of a suitable mixing trough:

		£	s.	d.
20 cwt.	of Cambridge coprolites, ground	3	5	0
17 "	of brown acid at £4 0 0.	3	8	0
5¼ "	of quicklime at 16s.	0	2	8
9 "	of water		*nil*	
Labor of mixing 2¼ tons of dry solid matters and wear and tear of troughs		0	2	4
2¼ tons of dry solid matter, containing 1,600 lbs. of tribasic phosphate of lime, cost		6	18	0

Being a little less than 2s. per unit for a material which Mr. Sibson values at 3s. 6d. per unit, delivered to the consumer in bags, carriage paid.

There would then appear to be a fair profit on the treatment of phosphatic materials, if introduced in this way, into a manure which would find a market. I shall now proceed to show that there is every probability of being able to dispose of this manure at a price approaching that at which its constituents would be valued by chemists.

Let us first, however, consider the value of the fertilizers already existing in the sludge, to which it is proposed to add lime, and subsequently a solution of superphosphate, and thus to precipitate the soluble phosphate. From the scale of prices by Mr. Sibson, given above, we shall have to deduct from the value assigned to ammonia 10 per cent., owing to the fact that in sludge that compound has no existence, nitrogen only, capable of forming it, being present. This will reduce the value to 18s. per unit, and our figures will stand thus:

66.50 organic matter (without nitrogen)		*nil*	
3.50 nitrogen (=4.25 ammonia at 18s. per unit)	£3	16	6
6.07 phosphate at 2s. 6d. per unit	0	15	2
1.25 potash (=2.30 sulphate of potash at 3s. 6d. per unit)	0	8	0
22.68 sand and other minerals		*nil*	
100.00	£4	19	8

In order to ascertain the quantity of precipitated phosphate which should be added to the manure, let us see what proportion is necessary to give the utmost effect to the above amount of ammonia. I should here point out that phosphates have been proved to be the ingredients without which plants cannot thrive, or even live. If any of the other mineral elements found in plants are absent from a soil, the plants may become stunted, and bear a very low crop of fruit, but they pass through the cycle of life; if phosphates are absent, however, they die. "Phosphates, therefore, not only aid themselves in the nutriment of plants, but they determine the beneficial action of the other mineral ingredients;" and, as Liebig says, "the phosphoric acid insures and increases the action of the ammonia." Dr. Voelcker is of opinion that, for a manure of general purposes, the proportion of the phosphate of lime should be to the ammonia of the manure as 4 is to 1. M. Ville specifies that the phosphate of lime should be to the ammonia in ratios varying from about 4 to $1\frac{1}{3}$ to 4 to $\frac{1}{2}$, according to the nature of the crop. If we assume, therefore, Dr. Voelcker's decision to be approximately correct for a general manure, we shall have to add to the sludge about $8\frac{1}{4}$ per cent. of precipitated phosphate, after which its composition and value would stand thus. But in order to avoid any appearance of making out too good a case for my project, I will value the finished manure on a scale which can scarcely be caviled at by the most arrant unbeliever in the efficacy of sewage manure. The valuation of the ammonia is that adopted by Dr. Voelcker in Messrs. Rawlinson and Read's report, namely, 8d. per pound. This price was based on the then market price, which was unusually low.

50.15 organic matter (without nitrogen)		*nil*	
2.64 nitrogen (=3.21 ammonia) at 15s. per unit	£2	8	2
4.58 phosphate associated with the sludge at 2s. per unit	0	9	2
8.23 precipitated phosphate (added to sludge at 2s. 6d. per unit)	1	0	7
1.73 potash sulphate (= .9 potash at 3s. 9d. per unit)	0	3	4
16.08 sulphate of lime, &c., from superphosphate		*nil*	
16.55 sand, &c		*nil*	
99.96			
Value estimated on the manure in the perfectly dry condition	£4	1	3

Dr. Voelcker, in reporting to Messrs. Rawlinson & Reed on samples of sludge manure submitted to him by them, says that: "It is manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commercial value of guano, bone dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night soil manures is attained by comparing them with ordinary farm-yard manure, and the price which is paid for the latter," and he expresses the opinion that the utmost a farmer can afford to pay for good dung of the theoretic value of 15s. per ton, if he has to cart it half a mile, would not exceed 7s. 6d., or half its estimated value.

On the other hand, he thinks that manures sell better at the value of £8 8s. per ton, than if they have a higher value. Manifestly therefore, if he is right in his view, at this price the theoretic and market values of manures should coincide. I think, indeed, I might venture to say, that he considers that they do so, even at the price of £6 per ton. Some deduction, in any case, must be made therefore, from the value at which the above estimate of the mixture of the prepared sludge and precipitated phosphate works out, and what this deduction should be may, perhaps, be best arrived at by following the course pursued by Messrs. Hofmann & Witt, to show the disadvantages of feeble manures. I may then, for simplicity's sake, suppose the one manure to have a value of £8, the other of £4, without entailing an error of any consequence. Thus:

	£	s.	d.
Price of one ton of good manure at the factory	£8	0	0
Spreading	0	0	9
	£8	0	9

	£	s.	d.
Price of two tons of sewage manure at factory	£8	0	0
Spreading	0	1	6
	£8	1	6

	£	s.	d.
Price of one ton of good manure at factory	£8	0	0
Carriage for two miles	0	2	0
Spreading	0	0	9
	£8	2	9

	£	s.	d.
Price of two tons of sewage manure at factory	£8	0	0
Carriage for two miles	0	4	0
Spreading	0	1	6
	£8	5	6

	£	s.	d.
Price of one ton of good manure at factory	£8	0	0
Carriage for five miles	0	5	0
Spreading	0	0	9
	£8	5	9

	£	s.	d.
Price of two tons of sewage manure at factory	£8	0	0
Carriage for five miles	0	10	0
Spreading	0	1	6
	£8	11	6

Therefore, at a distance of five miles, there is a relative disadvantage in using the sewage manure of 5s. 9d.; and, at a distance of two miles only, of 2s. 9d. If we say then, that the manure—allowing for 10 per cent. of water, which it should contain—has a value of £3 10s. per ton, we probably shall not be far from the price which would be given for it by farmers, when once they understood its merits, within a radius of four or five miles from the manufactory. In such situations as those which would be occupied by the works on either side of the river, the market would by no means be limited to a radius of five miles from them; for with water carriage, the farmers along the whole course of the river would probably draw their supplies of manure from these factories. If the sales would even cover the expenses of manufacturing the manure, as the process would be the means of keeping the most deleterious part of the sludge out of the river, it manifestly would be inexcusable to continue to throw the solids into the Thames. Let us see, then, what these expenses would be.

The first operation, when the supernatant water is drawn off from the deposit (which will consist of about nine parts of liquid to one of solid), is to add to the sludge about two-thirds per cent. of quick lime, slacked and made into milk of lime. This is effected by running the milk over it, and then stirring the compound, which will effectually deprive the sludge of noxious smell. The next step must be to mix with the limed sludge such a quantity of the prepared superphosphate as will nearly, but not quite, neutralize the lime previously added. The mixture now becomes surprisingly inodorous, considering the origin of the greater part of it; the organic matter also loses its slimy, glutinous nature; and assisted by the precipitated phosphates and the crystalline sulphate of lime, intimately incorporated with it, the compound drains and dries with comparative rapidity.

These additions will cost for materials about 16s. 6d. per ton of prepared manure, as may readily be seen by valuing the precipitated phosphate contained in it at the 2s. per unit which we found to be the cost of making it. To remove the sludge from the tanks and to dry it, including all the expenses of treatment, except the cost of building tanks, will amount to about 20s. per ton. This gives as the profit on the manure (£3 10s., less £1 16s. 6d.), £1 13s. 6d. per ton; or, say, £1 10s. per ton.

Sir Joseph Bazalgette estimated a few years since that, roughly speaking, each gallon of sewage water carries down with it 100 grains of suspended matters, and the daily discharge, Captain Calver says, is 120,000,000 gallons in dry weather. This would yield 279,225 tons of solid matter per annum, which quantity Captain Calver thinks too low an estimate. This estimate is, however, considerably higher than would follow from the analyses given by Hofmann & Witt, and by the Rivers' Pollution Commissioners. I do not think that it can be assumed that the organic matter is more than from 50,000 to 55,000 tons per annum, and if we add to this, for detritus and mineral matter, double its weight, as found in the outfall-sewage by Prof. Williamson,

we arrive at only 150,000 or 165,000 tons of solid suspended matters per annum; whereas, with Dr. Letheby's estimate, we should get no more than 116,000 tons, and from the analyses of the Rivers' Pollution Commissioners, and Drs. Hofmann & Witt, only 130,000 tons per annum. Concerning the quantity of solid organic matter in Thames sewage, we may speak with much more confidence, then, of the quantity of the solid mineral matter. Different estimates of the former vary less than 5 per cent.

Taking the lower of the above estimates, so as not to overstate my case—say, 150,000 tons—it may readily be seen from the analyses that we may reasonably hope to effect a rough separation of the deposit. Thus, in a first set of depositing tanks, we should keep back four-fifths of the heavier particles, entangling with them only a small proportion of the organic matter; and in a further set of tanks, in which the sewage would be brought to complete quiescence, we might recover four-fifths of the organic matter (or 40,000 tons), mixed with half its weight of mineral matter, making a total of 60,000 tons available for the manufacture of a manure.

To this 60,000 tons, we have to add about one-third for the phosphates, &c., mixed with them in the manufacture, giving us, as the total amount of manure, reckoned dry, 80,000 tons, or, with the moisture, which we will take at 10 per cent., say, 88,000 tons.

The question of what is to be done with the sand or silt deposit, amounting to 90,000 tons per annum, must also naturally suggest itself. What ought not to be done with it is quite certain; we ought not to cast it into the river. It may be quickly dealt with, and rendered perfectly clean, by passing it through one of Fryer's destructors, heated with waste cinders, which are now a drug in the market, and most difficult to dispose of; or it might be used for reclaiming a portion of the marshes at the expense of pumping it to some little distance, as was suggested by one of the Royal Commissions, in reference to the whole of the deposit. Surely, even this last plan would be preferable to putting it into the river and dredging it out again, and then having it still to dispose of.

If the Metropolitan Board take measures to keep out of the river the whole of the suspended matters which will deposit in tanks of a size moderate, as compared with the total volume of sewage water, they will have done much towards rendering the London sewage practically harmless, as will be readily apparent from the following statements in the reports of various Royal Commissions:—

"The chief part of the nuisance, arising from the discharge of sewage into the rivers and streams, may be obviated by simply arresting the solid matters in the liquid.

"By far the greatest part of the solid matter which is held in suspension in water is readily deposited in rivers, covering the banks with mud, permanently raising the beds, gradually destroying the scouring power and partially silting such rivers up.

"That, however, the appearance of the water may be improved after these deposits have taken place, yet the deposited matters lying in the bed of the current are under conditions favorable to putrefaction, and when the foul mud is disturbed by the prevalence of rain during floods, it sends forth its effluvia among the populations which are near, and even, in the course of the rivers, far distant."

In short, successive Royal Commissions have repeated the truths told to the Metropolitan Board by their own advisers, Messrs. Bidder, Hawksley and Bazalgette, in their report on the main drainage. They have further informed them that "covered reservoirs, of moderate size, ought to be constructed near each outlet, for the reception of the sewage water until it shall be discharged during the first hours of the descending tide, or to enable it to be defecated by lime or other chemical agent" (Report, p. 99) before admission into the river" with a view "to the realization of its fertilizing contents, if such should hereafter become commercially valuable." (Report, pp. 98 and 99.)

In the foregoing recommendation, then, I have not exceeded that which Sir Joseph Bazalgette himself thought imperative, upwards of 20 years ago, when his main drainage scheme was devised; but in order that the sludge to be used for manure may not be degraded by the

mixture with it of a bulky precipitate of carbonate of lime, I have suggested that the coarser mineral suspended matters may first be allowed to deposit in a subsidiary tank, and next, that the sewage may be given a period of greater rest in order that the suspended organic matters may separate from the liquid, and be made available for manurial purposes. Finally, I would urge upon the Metropolitan Board the importance of carrying out the recommendation of their present adviser, given when he was acting with the above gentlemen, and I would recommend them to take steps for making the defecation of the sewage perfect by precipitating it with milk of lime. Subsidence alone will not effect the perfection of clarification which the nation might fairly require, if the sewage of London is to be thrown into the noblest river they possess.

If this further treatment be undertaken it gives us another large quantity of worthless matter to be disposed of.

For by using 12 grains of lime per gallon, it would, with the carbonate of lime derived from the sewage water, and other matters thrown down, occasion a total deposit of quite 220,000 tons per annum. This I would deal with in one or the other, or all of the following methods:—

Firstly. By adding the proper proportion of clay to be obtained from the river banks with the requisite amount of milk of lime, so as to enable the deposit to be burned into Portland cement, as is now done at Burnley, under much less favorable conditions than would exist under the circumstances I have pointed out.

Secondly. By re-burning the precipitate, and using it for a fresh portion of sewage; this operation might be repeated six times, after which the calcined deposit might be used for the manure process, or it might be sold for phosphatic agricultural lime. The phosphoric acid thus recovered would be worth upwards of £20,000 per annum.

Thirdly. By selling the deposit as a top dressing for land, for which purpose farmers might be willing to give for it say 1s. per ton pumped into barges.

I have endeavored to put my suggestions to you without any exaggeration, and I now commend my estimates and figures to the attention of those interested in this question, and capable of examining into the accuracy of my deductions. The only point on which I myself see any grounds for doubt is on the question of what proportion of the detritus it is practically possible to separate from the organic matters. To effect such a separation as I have assumed, would not, I submit, be a difficult task for engineers, and the experiment could be made at a trifling expense. The cost of the tanks, if executed in concrete, would probably not exceed £100,000, and as the sale of the manure might be expected to realize £132,000 per annum, it would certainly be sufficient to cover the interest on this sum together with the expense of disposing of the sand.

I trust that the Metropolitan Board of Works will give their careful attention to these figures, and at any rate attempt to keep out of the river all that can be detained, without further taxing the rate-payers of the metropolis. The only reasonable objection that can be urged against my suggestions is that there might be a difficulty in finding a market for so large an amount of manure of a comparatively low standard. If those in authority turn a deaf ear to my arguments, I venture to hope that Parliament will intervene, and no longer bestow upon the Thames the unenviable distinction of being the only filthy river in the country.

It is stated—says *Nature*—that a new photographic process has just been discovered in Japan by an inventor whose name is not given. One of the substances employed in the manufacture of Japanese lacquer has the property of becoming almost as hard as stone under the action of light. A slab covered with this material and duly exposed behind a photographic "negative" for some twelve hours, was afterwards scraped and rubbed with spatula and brush, leaving the hardened portions raised in low relief, and capable of being used as a block for printing.

FORMULÆ FOR PILLARS.

By JOHN D. CREHORE.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

HAVING already treated this subject in an elementary manner, in numbers 118 and 132 of this ENGINEERING MAGAZINE, and finding an endorsement and further application, by Professor Ward Baldwin, in number 137, of the principle which characterizes my rational formula, I now return to the topic in order to call attention to a few points not yet sufficiently elucidated, and to adapt the formula for use within the elastic limit of material.

Prof. Baldwin referring to the Gordon formulæ, says: "There seems to have been no attempt to show that the formulæ now in general use are incorrect." Now it is plain that all properly derived *empirical* formulæ must be correct, on the average, for the experiments from which their constants were deduced, and for all like cases; and, if constants are established for each different form of cross section for different columns, the formulæ should accord with the tests. But when the Gordon formula, viz.:

$$Q=\frac{P}{S}=\frac{36000}{1+\frac{l^2}{3000h^2}} \quad . \quad . \quad (1)$$

which applies properly to wrought-iron pillars of rectangular cross section, is applied to all forms of cross section indifferently, palpable errors may be committed. And, indeed, this formula fails to discriminate between real differences in some important cases. Take, for example, an I-beam used as a strut or column, and compute its strength by formula (1); then suppose the same beam to be split through the web into two equal channels, and suppose further, the edges of the flanges united so that we have a tubular column of exactly the same area of cross section, and of the same dimensions, l and h, as before splitting. The formula will now give the same strength as before, but we all know that the tube is a much stronger column than was the I-beam, if, by splitting, the metal has not become too thin.

Hence, for this case, manufacturers, as Carnegie Brothers & Co., are obliged to introduce $r^2=\frac{I}{S}=$ the square of the least radius of gyration, in the place of h^2, and modify the constant 3,000.

Rankine's formula, viz.:

$$Q=\frac{P}{S}=\frac{36000}{1+\frac{l^2}{36000r^2}} \quad . \quad . \quad . \quad (2)$$

seems therefore preferable to the Gordon formula for general use, although it still has the constants deduced from rectangular wrought-iron pillars.

The ease with which the Gordon formula is applied, will doubtless prolong its existence, although it cannot enter into the peculiarities of cross section as do the formulæ which are expressed in terms of the least radius of gyration, r, instead of the least diameter, h. There seems to be a growing tendency of late, in important specifications, to employ r instead of h. This indicates progress.

I have elsewhere shown that both these formulæ fail, or rather, were not intended, for short pillars where Q is actually greater than the assumed constant in the numerator of the last member.

The rational formula above referred to, is,

$$Q=\frac{P}{S}=\frac{C}{1+\frac{Cl^2}{m\pi^2Er^2}} \quad . \quad . \quad . \quad (3)$$

where m stands for 1, 4, or about 2.28, according as we regard neither, both, or one only, of the pillars' ends fixed.

l=length of pillar.

r=least radius of gyration of cross section.

C=crushing strength of standard specimen of the material

P=breaking weight applied at the end of the pillar, and in the line of its axis before deflection.

S = area of cross section.
E = modulus of transverse elasticity.
Q = breaking weight per square inch of cross section, when all stresses are in pounds and all dimensions in inches.

Prof. Baldwin reproduces formula (3), modifies it for columns that fail on the extended side, and then proceeds to take the virtue out of the whole, in the following language:

"The fundamental hypothesis on which the above discussion depends is, that E, the modulus of elasticity, is constant. As is well known, however, this is not the case when the material is strained to near the ultimate strength, and hence it might be inferred that the general formulæ deduced on this hypothesis cannot be used to determine the ultimate strength of columns."

It is readily admitted that the value of E varies for different loads; but it is maintained that, for a given load at a given instant, E does *not* vary; and that in the "above discussion" the required load $Q=\frac{P}{S}$, was always assumed to be given in the sense of fixed in amount, at a given instant, and therefore the only variables in the fundamental equation were x and y.

To illustrate the variation of E for different loads on cast iron, I have arranged Table I from data found in Mr. Stoney's *Theory of Strains*, and in Mr. Kent's *Strength of Materials*.

This table shows the varying values of

TABLE I.—CAST IRON.

Hodgkinson's Experiments. Length of Bars, ... 120 inches. Cross Section, ... 1×1 square inches.						Kent's Experiments. 5 inches. $\pi\times(9\div16)^2$ square inches.		
Compression.			Tension.			Tension.		
Load. Tons, per sq. inch.	Decrement of length due last ton, inches.	E in tons of 2,240 lbs. per sq. inch.	Load. Tons, per sq. inch.	Increment of length due last ton. Ins.	E Modulus of Elasticity, lbs. per sq. in.	Load. Lbs. per square inch.	Extension in inches.	E in lbs. per square inch.
1	.020338	5,900	1	.01976	13,603,520	500	.0001	25,000,000
2	.021038	5,704	2	.02027	13,260,800	1,000	.0002	25,000,000
3	.021618	5,551	3	.02171	12,382,720	1,400	.0003	23,333,333
4	.021369	5,615	4	.02318	11,596,480	2,000	.0006	16,666,667
5	.021594	5,557	5	.02479	10,843,840	2,500	.0008	15,625,000
6	.021752	5,517	6	.02727	9,856,000	3,000	.0010	15,000,000
7	.021950	5,467	6.5	.02815.	9,549,120	4,000	.0013	15,384,615
8	.022154	5,416				5,000	.0018	13,888,889
9	.022374	5,363				6,000	.0022	13,636,364
10	.022477	5,339				7,000	.0026	13,076,923
11	.022567	5,317				8,000	.0032	12,500,000
12	.022802	5,262				9,000	.0037	12,162,162
13	.023014	5,214				10,000	.0041	12,195,119
14	.023523	5,101				11,000	.0047	11,702,128
15	.023539	5,098				12,000	.0054	11,250,000
16	.024409	4,916				13,000	.0059	11,016,949
17	.024805	4,838				14,000	.0066	10,606,061
						15,000	.0075	10,000,000
						16,000	.0085	9,411,706
						17,000	.0092	9,239,130
						18,000	.0101	8,910,891
						19,000	.0112	8,482,143
						20,000	.0125	8,000,000
						21,000	.0140	7,500,000
						22,000	.0160	6,875,000
						23,000	.0184	6,140,218
						23,285	Broke.	

E for cast iron, in direct compression and tension, on which the values of E for transverse elasticity depend.

It is here seen that E varies not only beyond the elastic limit, but through all the values of P within this limit, so that the ordinary modulus of elasticity is simply a mean of many values. In other words, each load and each increment of load, has a unique increment of length and a unique value of E. And the case of other materials is similar, though perhaps not so marked as for cast iron

The difficulty with the rational formula (3), lies not, therefore, in the variableness of E for a given value of Q or P; but, if it has a difficulty, it lies in assigning the correct simultaneous values to C and E, and in our want of knowledge of the sufficiency of the multiplier $\frac{C-Q}{C}$, at the instant of rupture.

If, when the deflection is great, just before rupture, we conceive the whole weight, P, borne by $\frac{1}{2}$ (say) of the cross section, S, then the intensity

$$Q=\frac{P}{S}=\frac{m\pi^2Er^2}{l^2}$$

of compression, is twice what it would be if P were distributed over the whole surface, and hence the third member must be multiplied by $2\left(\frac{C-Q}{C}\right)$ instead of $\frac{C-Q}{C}$.

TABLE II. STRENGTH OF PILLARS AT THE ELASTIC LIMIT, IN POUNDS PER SQUARE INCH OF CROSS SECTION.

	Wrought Iron.		Cast Iron.		Steel.	
K	$12\times2240=26,880$ lbs.		$15\times2240=33,600$ lbs.		$21\times2240=47,040$ lbs.	
E	24,000,000 "		12,000,000 "		30,000,000	
Ends.	Free.	Fixed.	Free.	Fixed.	Free.	Fixed.
m	1	4	1	4	1	4
$l\div r$	U	U	U	U	U	U
10	26,578	26,804	32,672	33,364	46,304	46,854
20	25,127	26,578	30,175	32,672	44,229	46,305
30	24,390	26,212	26,767	31,585	41,155	45,417
40	22,749	25,713	23,110	30,175	37,506	44,229
50	20,939	25,100	19,658	28,540	33,667	42,791
60	19,084	24,390	16,623	26,767	29,926	41,155
70	17,275	23,600	14,058	24,935	26,449	39,376
80	15,572	22,749	11,933	23,110	23,324	37,506
90	14,006	21,857	10,188	21,327	20,569	35,590
100	12,591	20,939	8,757	19,658	18,171	33,66[illegible]
110	11,326	20,011	7,580	18,082	16,096	31,771
120	10,205	19,084	6,607	16,623	14,308	29,926
130	9,213	18,170	5,799	15,283	12,766	28,147
140	8,337	17,275	5,122	14,058	11,435	26,449
150	7,565	16,407	4,551	12,944	10,284	24,842
160	6,883	15,571	4,006	11,933	9,283	23,324
170	6,292	14,770	3 653	11,017	8,413	21,901
180	5,748	14,006	3 297	10,188	7,652	20,570
190	5,274	13,279	2,989	9,437	6,984	19 328
200	4,853	12,591	2,721	8,757	6,396	18,164
210	4,477	11,941	2,487	8,140	5,835	17,096
220	4,140	11,327	2,281	7,580	5,413	16,096
230	3,838	10,749	2,100	7,071	5,002	15,169
240	3,567	10,205	1,938	6,607	4,634	14,308
250	3,322	9,693	1,794	6,185	4,304	13,508
260	3,100	9,212	1,665	5,799	4,007	12,76[illegible]
270	2,899	8,760	1,550	5,445	3,739	12,075
280	2,716	8,337	1,446	5,122	3,496	11,435
290	2,550	7,939	1,366	4,824	3,275	10,863
300	2,397	7,565	1,266	4,551	3,075	10,283

$$\therefore \quad Q=\frac{C}{1+\frac{\frac{1}{2}Cl^2}{m\pi^2Er^2}} \quad . \quad . \quad (4)$$

Or, in general, if S_1 is that part of the pillar's cross section, actually receiving the whole compression, then the multiplier of $\frac{m\pi^2Er^2}{l^2}$ becomes $\frac{S}{S_1}\left(\frac{C-Q}{Q}\right)$, and the final value of Q is

$$Q=\frac{P}{S}=\frac{C}{1+\frac{S_1Cl^2}{m\pi^2SEr^2}}, \quad . \quad . \quad (5)$$

where C, E, P, and Q, are simultaneous, and at the instant of rupture. Now, if E varies sensibly with S_1, and if $S_1=S$ approximately, within the elastic limit, the rational formula (3) is practically correct. And that E does vary sensibly with S_1, is inferred from the accordance of results yielded by the rational formula (3) and by experiment.

May it not, therefore, be considered a point legitimately assumed in the argument which established the rational equation (3), that although E at the instant of rupture was less than E at the limit of elasticity, yet the numerator of the simple fraction in which E occurs, was also less in the same ratio, so that the coëfficient of $\left(\frac{l}{r}\right)^2$ remained constant?

In regard to the effect of passing through the different values of E as we go from cross section to cross section of a given column, in the process of integration under a given load, it seems clear that for any abnormal change in E there is also an abnormal change in R, the radius of curvature, and that, as both these changes result from the same cause, they compensate each other in the expression for the moment, $\frac{EI}{R}$; and hence, practically, the ordinary integration is not vitiated.

In order to avoid all uncertainty attending the values of C and E at the instant of rupture, I propose the formula

$$U=\frac{V}{S}=\frac{K}{1+\frac{Kl^2}{m\pi^2Er^2}}, \quad . \quad . \quad . \quad (6)$$

where E, K, V, and U are simultaneous and within the elastic limit.

V=whole load upon the pillar.

$U=\frac{V}{S}$=mean load on unit of cross section.

K=total unit strain on the compressed material.

E=modulus of transverse elasticity, as before.

Table II gives the values of U in pounds per square inch, computed from equation (6), for wrought iron, cast iron, and steel, using values assigned by Mr. Stoney for E and K, and remembering that the ends are fully fixed, or wholly free to turn.

We may take a third of the value of U for any case in Table II, as the safe working load, when the metals yield these values of K and E. But the true values of K and E should be determined for every quality of metal used.

It will be noticed in the first two series of Table I, that E is derived from the change of length due to the latest added ton, while in the last series E is computed from the total elongation due the total load, without initial strain.

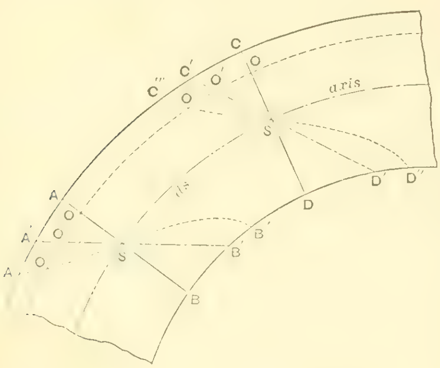
ON A GENERAL FORMULA FOR THE NORMAL STRESS IN BEAMS OF ANY SHAPE.

By GEORGE F. SWAIN, S. B., Providence, R. I.

Contributed to VAN NOSTRANDS'S ENGINEERING MAGAZINE.

In deducing the ordinary formula for the normal stress in beams, the assumption is generally made that plane sections at right angles to the axis of the beams before the deformation remain plane after it. The investigations of de St. Venant have shown us that this assumption is in general incorrect, and have taught us how to find—in certain special cases, and under certain other assumptions—the equation to the deformed section. In fact, it is easy to see that a shearing force in the plane of the section must alter the inclination to the axis

of the beam of the element on which it acts; and if, as is generally the case, the shearing force is unequally distributed over the section, the inclinations of the various elements of that section to the axis will be different, and the section cannot remain plane. An exact determination of the deformation of a beam has, I believe, never been effected, and considering that we are as yet obliged to make assumptions regarding the nature of our materials, it may be looked upon as impossible. Moreover, even supposing us to be acquainted with the exact nature of our materials—their axis of elasticity and the relations between stress (force) and strain (deformation)—the problem of determining the exact state of stress and strain in any part of a body acted upon by given forces, presents enormous difficulties, and has never, to the best of the author's knowledge, been solved.



The equation of the deformed section, under the assumptions generally made in the higher treatment of the subject, as given by de St. Venant, Clebsch, Groshaf, Winkler and others, is found to be in most cases of a degree higher than the first, and only in some very simple cases is it of the first degree, the sections remaining planes and normal to the axis. But in some other cases the assumption that the sections remain plane, though incorrect, may lead to some correct results. Suppose, for instance, to take a simple case, that we have a beam whose axis lies in a plane, and that the outer forces also act in this plane, and that the axis of the beam remains in this plane during the deformation. Let the section AB take the position A''B'' after the bending, instead of A'B', and let the section CD take the position C''D'', the two sections being at an infinitesimally small distance, ds, apart, measured along the axis. The state of normal stress between these two sections, the plane of the paper representing the plane of the axis, will be the same as though AB and CD had become A'B' and C'D', provided that $o'o''=o_1'o_1''$, for in that case $o''o_1''=o'o_1'$ and $o''o_1''-oo_1$, will vary directly as the distance from the line of no stress, or neutral axis. (The figure is drawn as though that line cut the axis of the beam, but this is not necessary). If the sections were deformed in this way, then the assumption of plane sections would give correct expressions for the normal stress.

The assumption that the sections remain plane amounts, in fact, as far as the strains are concerned, to the assumption that the strain (*not its intensity*) varies directly as the distance of the strained fiber from a straight line in the plane of the section, the neutral axis, but we see that the latter supposition does not require that the sections remain plane, and if it is the only supposition regarding the strains which it is necessary to make in deducing the formulæ for the stresses, then these formulæ do not require the sections to remain plane. We shall see that this is the case, and in the following demonstration we shall make the assumption that the strain on any fiber—that is, its change of length—may be expressed by an equation of the first degree, and we repeat that this does not require that the sections remain plane, although the results to which it conducts are the same as would be obtained under the latter supposition, for although this latter is only a special case of the one we make, yet the common element of both, so to speak, is the only one which we shall use in our investigation.

We may remark that in some simple cases the section after the deformation might be generated by a straight line at right angles to the plane of the axis; but that in others, for example when there is not only a shearing force in the plane of osculation, but also in a plane at right angle to it, the sections may become warped surfaces. In fact, the number of forms which they may assume, without violating the above assumption, is infinite in number.

Let us suppose a beam of any shape, with axis curved in space, and acted upon by any forces. At any section at right angles to the axis we assume three rectangular co-ordinate axes x, y, z. We take x tangent to the axis of the beam, and positive toward the right; it passes through the center of gravity o, of the section. We take the xz plane as the osculatory plane of the axis in the point o, the z axis positive upward, the y axis perpendicular to the osculatory plane in o, and positive toward the observer. We have supposed the axis of the beam given. Its determination may in many cases be difficult, for the axis may be defined as a line passing through the centers of gravity of all sections normal to it, hence a determination of the position of the sections supposes the axis already known, and the latter can in many cases only be found by a tentative process. Supposing, however, the axis known, let us consider the part of the beam to the left of the section, and apply at each element of that section the stress exerted upon it by the part of the beam to the right, which we suppose removed. Resolve all the outer forces (not the last-mentioned *stresses*) acting on the part of the beam under consideration into three forces, P_x, P_y, P_z, acting through o and parallel to the three co-ordinate axes, and three moments, M_x, M_y, M_z, acting about those axes. The part of the beam considered is in equilibrium under the action of these forces and moments, together with the stresses acting on the elements of the section. If we suppose that on an element df of the section the force kdf acts, and if we resolve this force into three rectangular components, N, S_y, S_z, acting in the direction of the axes x, y and z, respectively, and if we furthermore consider all forces positive when they act in the positive direction of the axis to which they are parallel, and all moments positive when, if viewed from the positive extremity of the axis about which they act, they are right-handed, then we shall have the following six conditions of equilibrium between the outer forces and moments, and the inner or molecular forces acting at the section:

$$\Sigma N df + P_x = o \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\Sigma S_y\, df + P_y = o \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\Sigma S_z\, df + P_z = o \quad . \quad . \quad . \quad . \quad (3)$$

$$\Sigma S_y\, df\, z + \Sigma S_z\, df\, y + M_x = o \quad . \quad (4)$$

$$\Sigma N df.\, z + My = o, \quad . \quad . \quad . \quad (5)$$

$$\Sigma N df.\, y + M_z = o. \quad . \quad . \quad . \quad (6$$

the summation being in each case extended over the whole section. It is not the purpose of this paper to investigate the distribution of stress over the section in all its generality, but simply to find an expression for the normal stress N. We shall, therefore, pay no further attention to the forces P_y, P_z, or to the moment M_x, for they only cause shearing stresses in the plane of the section. It will also be convenient if we alter our method of designation, and consider P_x positive when it acts in the direction of the negative x axis, and M_y positive when, if viewed as above, it is left-handed. Making these changes, leaving out of account the equations (2), (3) and (4), and changing the Σ to a $\int$ we have as our conditions of equilibrium:

$$P_x = \int N df \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$M_y = \int N z\, df \quad . \quad . \quad . \quad . \quad (5)$$

$$M_z = \int N y\, df \quad . \quad . \quad . \quad . \quad (6)$$

The first equation expresses the condition that the axial force P_x equals the total normal force acting at the section, while the last two express the equality of moments about the axes of y and z, n being positive when it acts toward the right. A positive N represents tension, and a negative N represents compression.

We are considering the beam in its deformed condition. The outer forces are acting, the fibers are subjected to a strain; the axis of the beam has changed its position. At the outset, then, we are unacquainted with the form of the beam we are considering. We know its form when unaffected by forces, but are ignorant of the deformation it undergoes. We are unable to fix the plane of osculation at any point, or the co-ordinate axes x, y, and z, hence we cannot calculate P_x, M_y, M_z, nor find the state of stress in the beam until we have first learned the exact nature of the deformation which those very forces and moments produce. But in order to determine the deformation, we must first learn the state of stress on each part of the beam, and then, combining this knowledge with certain assumptions regarding the

nature of our materials, we can arrive at some conclusions regarding the deformation. We see, then, very clearly here the difficulty—one difficulty—of the problem of finding the exact state of stress and strain. The stress and the strain are functions of each other. In order to find either, some assumption respecting the other must be made. For example, if we assume the deformation we can determine the outer forces and moments, and by discussing the equations of equilibrium written down above, we can find the stresses, and from these the strains, or the movements which the particles have gone through in arriving at the deformed condition; and by considering these movements to be gone through with in the reversed direction, we can see whether the beam would be brought back to its original known shape in a state of repose. If this is not the case, our assumption of the deformation was incorrect. There is, however, another solution of the problem, founded on the fact that in practice the deformations are always very small compared with the dimensions of the beam. We assume, namely, that the deformation is *zero*, determining the outer forces, and from them the inner forces or stresses, under the supposition that the beam retains its original shape, which is supposed to be exactly known. This is the supposition generally made in treating of this subject, and we wished to call attention to its inaccuracy, although its results are practically as correct as we need them. In the rest of this paper we shall consider the beam in its deformed condition, supposed known. In practice the above supposition enables us to compute very close approximations to the value of P_x—M_y, etc., which enter into our equations.

Let ds be the distance between two sections, measured along the axis. ds is supposed infinitesimally small. Since the two sections are normal to the axis, they are parallel to the axis of y, and the distance between them at all points at a distance z from the y axis is

$$ds_z = ds + z d\varphi, \quad . \quad . \quad . \quad (7)$$

$d\varphi$ being the angle between the sections $= \frac{ds}{r}$.

The intensity of the normal stress at any point of the section equals the intensity of strain multiplied by the modulus of elasticity, E. Assuming, then, that the strain on any fiber is expressed by an equation of the first degree, or, S being the strain, and a', b', c', constants,

$$S = (a' + b'z + c'y)\, ds \quad . \quad . \quad . \quad (8)$$

we shall have for the intensity of the strain,

$$\frac{S}{ds_z} = \frac{(a' + b'z + c'y)ds}{ds + zd\varphi} \quad . \quad . \quad . \quad (9)$$

and for N the value

$$N = E\frac{a' + b'z + c'y}{ds + zd\varphi} ds = \frac{a + bz + cy}{ds + zd\varphi} . ds \ldots (10)$$

a, b, c, being new constants.

If the sections were plane before the deformation, the distance between them at any point must have been expressed by an equation of the first degree, or ds' being the distance,

$$ds' = ds(k + lz + my) \quad . \quad . \quad . \quad (11)$$

Hence the strain is

$$ds_z - ds' = ds(1 - k) + z(d\varphi - l) - my . (12)$$

and as this is an equation of the first degree ($d\varphi$ being a constant for all points in the same section) this case is a special case of the more general one assumed above.

Substituting in equation (10) $\frac{ds}{r}$ for $d\varphi$, r being the radius of curvature of the axis in o, we have

$$N = \frac{a + bz + cy}{r + z} r \quad . \quad . \quad . \quad (13)$$

Substituting this value in the equations (1), (5), (6), we have the three conditions of equilibrium.

$$P_x = ar\int\frac{df}{r+z} + br\int\frac{zdf}{r+z} + cr\int\frac{ydf}{r+z} \quad . \quad . \quad . \quad (14)$$

$$M_y = ar\int\frac{zdf}{r+z} + br\int\frac{z^2df}{r+z} + cr\int\frac{yzdf}{r+z} \quad . \quad . \quad . \quad (15)$$

$$M_z = ar\int\frac{ydf}{r+z} + br\int\frac{zydf}{r+z} + cr\int\frac{y^2df}{r+z} \quad . \quad . \quad . \quad (16)$$

the integration being in each case extended over the whole section. Now we have the following equations:

$$\frac{r}{r+z}=1-\frac{z}{r+z}=1-\frac{z}{r}+\frac{z^2}{r(r+z)} \quad . \quad . \quad . \quad (17)$$

$$\frac{rz}{r+z}=2-\frac{z^2}{r+z} \quad . \quad . \quad . \quad . \quad (18)$$

$$\frac{ry}{r+z}=y-\frac{yz}{r+z} \quad . \quad . \quad . \quad . \quad (19)$$

Substituting these values in equations (14), (15) and (16), and putting for abbreviation

$$\int\frac{z^2 r df}{r+z}=\mathrm{I}_0\,;\ \int\frac{r y^2 df}{r+z}=\mathrm{I}_0'\,;$$

$$\int\frac{rzydf}{r+z}=\mathrm{H}_0,$$

the equations (14), (15) and (15) become

$$\mathrm{P}_x=a\int df-\frac{a}{r}\int zdf+\frac{a}{r}\int\frac{z^2df}{r+z}+b\int zdf-b\int\frac{z^2df}{r+z}+c\int ydf-c\int\frac{yzdf}{r+z} \quad . \quad . \quad . \quad (20)$$

$$\mathrm{M}_y=a\int zdf-a\int\frac{z^2df}{r+z}+br\int\frac{z^2df}{r+z}+cr\int\frac{yzdf}{r+z} \quad . \quad . \quad . \quad (21)$$

$$\mathrm{M}_z=a\int ydf-a\int\frac{yzdf}{r+z}+br\int\frac{yzdf}{r+z}+cr\int\frac{y^2df}{r+z} \quad . \quad . \quad . \quad (22)$$

or, putting $\int df=\mathrm{F}$, and observing that since the axes of y and z pass through the center of gravity 0 of the section, we have $\int zdf=o : \int yaf=o$, we have finally,

$$\mathrm{P}_x=a\mathrm{F}+\frac{a\mathrm{I}_0}{r^2}-\frac{b\mathrm{I}_0}{r}-\frac{c\mathrm{H}_0}{r} \quad . \quad . \quad . \quad (23)$$

$$\mathrm{M}_y=-\frac{a\mathrm{I}_0}{r}+b\mathrm{I}_0+c\mathrm{H}_0 \quad . \quad . \quad . \quad (24)$$

$$\mathrm{M}_z=-\frac{a\mathrm{H}_0}{r}+b\mathrm{H}_0+c\mathrm{I}_0' \quad . \quad . \quad . \quad (25)$$

From these equations we find the following values of the constants a, b, c:

$$a=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r} \quad . \quad . \quad . \quad (26)$$

$$b=\frac{\mathrm{M}_y\mathrm{I}_0'-\mathrm{M}_z\mathrm{H}_0}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}+\frac{\mathrm{P}_x}{\mathrm{F}r}+\frac{\mathrm{M}_y}{\mathrm{F}r^2} \quad . \quad . \quad . \quad (27)$$

$$c=\frac{\mathrm{M}_z\mathrm{I}_0-\mathrm{M}_y\mathrm{H}_0}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2} \quad . \quad . \quad . \quad (28)$$

Substituting these values in equation (13) for it, we find

$$\mathrm{N}=\frac{r}{r+z}\Big\{\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_y\mathrm{I}_0'z}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}-\frac{\mathrm{M}_z\mathrm{H}_0z}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}+\frac{\mathrm{P}_xz}{\mathrm{F}r}+\frac{\mathrm{M}_yz}{\mathrm{F}r^2}+\frac{\mathrm{M}_z\mathrm{I}_0y}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}-\frac{\mathrm{M}_y\mathrm{H}_0y}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}\Big\}$$

$$=\frac{r}{r+z}\Big\{\frac{\mathrm{P}_x}{\mathrm{F}}\cdot\frac{r+z}{r}+\frac{\mathrm{M}_y}{\mathrm{F}r}\cdot\frac{r+z}{r}+\frac{\mathrm{M}_y(\mathrm{I}_0'z-\mathrm{H}_0y)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}+\frac{\mathrm{M}_z(\mathrm{I}_0y-\mathrm{H}_0z)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}\Big\}$$

$$=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_y(\mathrm{I}_0'z-\mathrm{H}_0y)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}\,\frac{r}{r+z}+\frac{\mathrm{M}_z(\mathrm{I}_0y-\mathrm{H}_0z)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}\,\frac{r}{r+z} \quad . \quad . \quad . \quad (29)$$

This is the most general value of the normal stress. We distinguish the following particular cases:

1°. r=infinity. Here $\frac{r}{r+z}=1$, hence

$$\mathrm{N}=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y(\mathrm{I}_0'z-\mathrm{H}_0y)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}+\frac{\mathrm{M}_z(\mathrm{I}_0y-\mathrm{H}_0z)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2} \quad . \quad . \quad . \quad (30)$$

which is the general formula for a straight beam.

2°. $\mathrm{H}_0=o$. Here we have

$$\mathrm{N}=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_yz}{\mathrm{I}_0}\,\frac{r}{r+z}+\frac{\mathrm{M}_zy}{\mathrm{I}_0'}\,\frac{r}{r+z} \quad . \quad . \quad . \quad (31)$$

This is the formula for the case when the section is symmetrical about the axis of z.

3°. $r=\infty$; $\mathrm{H}=o$:

$$\mathrm{N}=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_yz}{\mathrm{I}_0}+\frac{\mathrm{M}_zy}{\mathrm{I}_0'} \quad . \quad . \quad . \quad (32)$$

This is the formula for straight beams one of whose principal axes lies in the osculatory plane.

4 . $r=\infty$; $\mathrm{H}=o$; $\mathrm{P}_x=o$; $\mathrm{M}_z=o$:

$$\mathrm{N}=\frac{\mathrm{M}_y z}{\mathrm{I}_0}, \text{ the well-known formula} \ldots (33)$$

The general formula (29) has, so far as the author knows, never before been published. The method used in deducing it, however, is identically the same as the one believed to have been first used by Dr. Winkler, who in his "Lehre von der Elasticität und Festigkeit" (Prag. 1867, page 50) deduced by its means the formula for straight beams

$$\mathrm{N}=\frac{\mathrm{P}}{\mathrm{F}}+\frac{\mathrm{M}(\mathrm{I}_0'z-\mathrm{H}_0 y)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2} \quad . \quad . \quad . \quad (34)$$

In his treatment of curved beams, however, he does not deduce eq. (29), but gets the formula

$$\mathrm{N}=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_y zr}{\mathrm{I}_0(r+z)}, \text{ cor. to eq.} \ . \ . \ (31)$$

The above demonstration has, in common with all others on this subject, assumed the truth of Hooke's law. It is well known that for stresses near the breaking point this law is not true. Prof. Winkler, in his above mentioned book, page 74, has assumed that the normal stress, instead of varying directly as the strain, may be expressed by two terms, one containing the first power, and the other the third power of the strain. He arrives in this way at expressions for the coefficient of rupture for sections of any form.

We have assumed that the strain varies directly as the distance from a straight line in the plane of the section. To find the intensity of the strain, we divide the strain on any fiber by the length of that fiber. We have also assumed that the intensity of the stress varies as the intensity of the strain, but in consequence of the length of the various fibers between the sections being variable, the stress does not in general vary directly as the distance from any line. In fact, equation (29) shows that N is not linear with regard to the co-ordinates. In case 1°, where the radius is infinity, equation (30) shows that N is linear with regard to the co-ordinates; hence the stress varies, directly as the distance from a line of no stress, the neutral axis. To find the equation to the line of no stress in the general case, put for N zero in equation (29), and we obtain as the equation of the neutral axis:

$$o=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_y(\mathrm{I}_0'z-\mathrm{H}_0 y)}{\mathrm{I}^0\mathrm{I}_0'-\mathrm{H}_0^2}\ \frac{z}{r+z}$$
$$+\frac{\mathrm{M}_z(\mathrm{I}_0 y-\mathrm{H}_0^2)}{\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2}\ \frac{r}{r+z} \quad . \quad . \quad (35)$$

As this equation is linear—as is seen by multiplying through by $(r+z)$—we see that the neutral axis is always a straight line. This must, of course, be so, because the assumption in equation (8) shows that the strain is zero along a straight line, and where the strain is zero the stress must be zero. In fact, equation (35) is identical with the equation, $a+bz+cy=o$, as will be easily found by substituting the values of the constants. As equation (35) is not satisfied by the values, $y=o$: $z=o$, it follows that the neutral axis does not pass through the center of gravity of the sections, even when $\mathrm{P}_x=o$. But if P_x and M_y are both zero, or if $\mathrm{P}_x=o$, and $r=\infty$, then the neutral axis will pass through O. By transposing equations (35) it may be written

$$y[\mathrm{M}_y\mathrm{H}_0-\mathrm{M}_z\mathrm{I}_0]\mathrm{F}r^2=$$
$$z[(\mathrm{P}_x r+\mathrm{M}_y)(\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2)$$
$$+(\mathrm{M}_y\mathrm{I}_0'-\mathrm{M}_z\mathrm{H}_0)\mathrm{F}r^2]$$
$$+(\mathrm{P}_x r+\mathrm{M}_y)(\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2)r \ldots (36)$$

hence the tangent of the angle which the neutral axis makes with the axis of y is

$$\tan.\theta=$$
$$\frac{(\mathrm{M}_y\mathrm{H}_0-\mathrm{M}_z\mathrm{I}_0)\mathrm{F}r^2}{(\mathrm{P}_x r-\mathrm{M}_y)(\mathrm{I}_0\mathrm{I}_0'-\mathrm{H}_0^2)+(\mathrm{M}_y\mathrm{I}_0'-\mathrm{M}_z\mathrm{H}_0)\mathrm{F}r^2} \quad . \quad . \quad . \quad (37)$$

This angle will be zero, or the neutral axis will be parallel to the axis of y when

$$\mathrm{M}_y\mathrm{H}_0-\mathrm{M}_z\mathrm{I}_0=o \quad . \quad . \quad . \quad (38)$$

We have seen that the equation for N is not linear. An investigation of the properties of this equation would be without practical importance, but we may state that in the form which it takes when $\mathrm{H}_0=o$ and $\mathrm{M}_z=o$, namely,

$$\mathrm{N}=\frac{\mathrm{P}_x}{\mathrm{F}}+\frac{\mathrm{M}_y}{\mathrm{F}r}+\frac{\mathrm{M}_y zr}{\mathrm{I}_0(r+z)} \quad . \quad . \quad . \quad (39)$$

which represents the most common case

in practice, N does not vary with y, and that if N be plotted at right angles to the section along the Z axis, the curve obtained will be a hyperbola, one of whose asymptote passes through the center of curvature of the axis in O, and is parallel to the axis of X.

With reference to the deformations, we wish to make one more remark which is of interest: Let us take the case of a beam whose axis lies in a plane, in which also the outer forces act—the most common case in practice. M_2 is here zero; and the conditions that the neutral axis shall be parallel to the axis of y becomes simply, $H_0 = o$. In this case, as shown by equation (39), the stress will be constant along all lines parallel to y, and each section, during the deformation, rotates about the neutral axis, so that the axis of the beam remains in its original plane. In any other case we cannot assent that this will be the case. The condition $H_0 = o$ is the same as

$$\int \frac{zydf}{r+z} = o \quad . \quad . \quad . \quad (40)$$

For straight beams this becomes

$$\int zydf = o \quad . \quad . \quad . \quad (41)$$

It is clear that the last equation will be satisfied when the section is symmetrical with respect to the axis of z or y, for then for each positive value of ydf or zdf there will be an equal negative value, and the sum of all the values over the whole section will be zero, identically. But it is well known that any section, whether symmetrical or not, has two axes at right angles to each other, for which the equation (41) is fulfilled. These axes are called the principal axes, and we have the theorem: *The axis of a straight beam, acted upon by forces in a plane, will only remain in that plane when one of the principal axis of each section lies in that plane.* It is believed that this theorem was first stated by Persy.

The ordinary equation for the normal stress in straight beams, $N = \frac{M_y z}{I_0}$, only applies, then, *when one principal axis of the section lies in the plane of the outer forces.* It is sometimes erroneously applied in other cases.

MR. LAW'S REPORT ON THE TAY BRIDGE.

From "The Engineer."

Mr. Henry Law, M.I.C.E., was employed by Mr. Rothery, Mr. Barlow, and Col. Yolland to examine the Tay Bridge after the fall of a portion of it, and to prepare a report thereon. This report constituted an important portion of the evidence adduced during the trial. We reproduce it complete.

To the Commissioners for the Tay Bridge Casualty.

Gentlemen:—In obedience to the instructions contained in your communication of the 22nd of January, 1880, I have now the honor to lay before you the following Report, embodying the information which I have been able to obtain upon those matters which have a bearing upon the casualty which occurred to the Tay Bridge, on the night of the 28th of December, 1879.

In accordance with your subsequent instructions, in the present report I have confined my attention exclusively to that portion of the bridge which has fallen; and for the sake of brevity and distinctness, I have omitted all reference to those details and particulars of the structure, which, although they may have an important bearing upon the question of reconstruction, have no connection with the cause of the catastrophe.

The bridge, as constructed, consisted of 85 spans, namely, 28 still standing upon the southern side of the river, varying in span from 67 ft. to 145 ft., 13 spans which have fallen, and 44 still standing on the northern side of the river, and varying in span from 162 ft. 10 in. to 28 ft. 11 in.

It will not be necessary to refer to the construction of any other portion of the standing parts of the bridge beyond the two spans immediately contiguous to those which have fallen.

These consist of wrought iron lattice girders resting upon piers, each of which

is composed of six cast iron columns, braced with wrought iron struts and ties, resting upon foundation piers of masonry, brickwork and concrete. The southern span is 145 ft., and the northern span is 162 ft. 10 in. Each girder is 16 ft. 6 in. in height, and their distance apart, from center to center, varies from 9 ft. at their in-shore ends to 14 ft. 10 in. at the ends adjacent to the fallen spans.

These girders rest upon seven cast iron rollers, bearing upon raised surfaces on thick cast iron bearing plates, the rollers having beveled flanges to serve as guides, but there being no attachment between the girders and the piers. The ends of these girders are strengthened to enable them to carry the ends of the larger girders which have fallen, forming a table or shelf upon which the latter girders rested, three cast iron rollers being interposed to allow the girders to expand or contract. These rollers were provided with flanges similar to those below, but there was no attachment between the upper and lower girders. The upright ends of the lower girders were steadied by two transverse wrought iron girders, one at the top and the other at the bottom, with diagonal tee iron stays.

In the portion of the bridge yet standing, the rails are carried upon traverse timber beams laid upon the upper surface of the girders, but in the portion which has fallen the rails were carried upon traverse wrought iron beams, resting upon and secured to the lower booms of the girders.

The length of the portion of the bridge which has fallen is 3,149 ft., consisting of three separate girders, the southernmost one being 1,225 ft. in length, divided into five equal spans, each of 245 ft., the middle girder being 944 ft. in length, divided into four spans, of which the two outer ones are each 227 ft., and the two inner ones each 245 ft., and the northernmost girder, which is divided into four equal spans, each of 245 ft. It will thus be seen that the fallen portion of the bridge consisted of 11 spans, each of 245 ft., and two spans, each of 227 ft.

The gradient of the railway over the southern standing portion of the bridge is a rising one of 1 in 35.368, and this gradient was continued over the first span. Over the second span the gradient changed to 1 in 490, still rising: the line then continued level for six spans, this being the most elevated portion of the bridge; the next span had a falling gradient of 1 in 130, and the remaining four spans had a falling gradient of 1 in 73.56, which continues over nearly the whole of the northern portion of the bridge.

The course of the railway over the fallen portion of the bridge, and for a considerable distance upon each side of it, was a continuous straight line.

The fallen portion of the bridge consisted of wrought iron lattice girders 27 ft. in height, placed at a distance of 14 ft. 10 in. apart from center to center. The upper and lower booms were trough shaped, being each 2 ft. in width, and between 15 in. and 16 in. in depth. The girder over each span was complete within itself, the vertical ends being of similar section to the booms, only 18 in. in width upon the face; the lattice bars, which had only a tensile strain to resist, consisted of flat bars in pairs, one being riveted to each side of the booms; those which were in compression consisted of I-shaped struts placed between the sides of the booms, and secured to them and to the tensile bars at their intersections.

The upper booms were braced by transverse wrought iron beams with diagonal stays. The railway was carried upon transverse wrought iron fish-bellied girders about 5 ft. 5 in. apart, which rested upon the upper side of the lower booms, and being riveted thereto served as struts to the girders, the bracing being rendered complete by diagonal angle iron stays, crossing through the center of each alternate transverse girder. In order to lessen the transverse strain upon the bottom boom, suspension bars of wrought iron were attached to the lattice bars at their intersections, and riveted at their lower extremities to the sides of the boom.

The various parts of these girders have been carefully proportioned to the several strains to which they had to be exposed, and as the catastrophe did not result from the failure of these girders, it is not necessary more particularly to describe them. It is, however, desirable to make an observation with reference to how far each division should be regarded as having formed a continuous girder.

As already mentioned, each girder was complete in itself, and the booms of these separate girders were connected by cover plates with the intention of making them continuous; but in the face of the evidence given at Dundee, of the manner in which these connections between the girders were made, I do not think that these divisions can be considered to have been continuous in such a manner as to produce an increased pressure upon any of the piers. It was stated by William Oram—Question 6494—that the connecting cover plates were temporarily secured by service-bolts, which were afterwards removed and replaced by rivets; the bridge in the meantime being used for the passage of heavy ballast trains—Questions 6821 to 6825. It is true that the ends of the girders had been originally raised before the cover plates were bolted on; but it must be evident that no strain such as would produce continuity in the girders in the sense now under consideration could have existed, for if it had it would have been quite impossible to have removed any of the bolts.

Judging from the portion of the bridge which is standing, the permanent way appears to have been very carefully constructed. The rails are laid upon longitudinal timbers, or way-beams, 18 inches wide by 15 inches in depth, the rails themselves are of steel, 75 lbs. to the yard, with guard rails of the same weight and material, both rails being secured in the same chairs, which are placed 3 feet apart; a flat wrought iron tie bar is also introduced at distances of about 19 feet apart to preserve the line in gauge.

The platform of the bridge was formed of planks 4 inches in thickness, covered with asphalte and with a few inches of ballast as a preservative against fire.

I now proceed to describe the most important part of the structure in connection with the subject under consideration, namely, the piers upon which the fallen portion of the bridge was supported.

These piers each consisted of an assemblage of six cast iron columns, braced by means of wrought iron studs and ties. Their foundations consisted of hexagonal-shaped piers of concrete, faced with brickwork, measuring 27 feet 6 inches in length from point to point of the cutwaters, and 15 feet 6 inches in width. These piers were carried to a height of 5 feet above the level of high-water of spring tides, the upper four courses being faced with stone, and no movement or settlement appears to have taken place in them.

The height from the top of the upper course of the masonry to the under side of the lattice girders varies from 83 feet to 81 feet 3 inches; in the following description, and in all the calculations the highest pier is referred to; as, however, the height of the pier affected the strength, it may be desirable to give in a tabular form the heights of the several piers above the masonry and the spans of the girders which they supported; the numbers in the first columns are the numbers of the piers in the structure, counting from the southern side, and, to avoid confusion, will be adhered to throughout this report.

No. of pier.	Height of pier.		No. of span	Width of span.	Description of bearing on pier.
	ft.	in			
28	67	6	29	245	3 rollers on lower girders.
29	82	6	30	245	8 rollers on pier.
30	83	0	31	245	8 rollers on pier.
31	83	0	32	245	Bolted to top of pier.
32	83	0	33	245	8 rollers on pier.
33	83	0	34	227	6 rollers and an expansion joint.
34	83	0	35	245	8 rollers on pier.
35	83	0	36	245	Bolted to top of pier.
36	83	0	37	227	8 rollers on pier.
37	82	8	38	245	6 rollers and an expansion joint.
38	82	4	39	245	8 rollers on pier.
39	82	0	40	245	Bolted to pier.
40	81	8	41	245	8 rollers on pier.
41	66	10	—	—	3 rollers on lower girders.

Cast iron base pieces, 2 feet in height, for the reception of the columns, were secured to the piers, each piece having four holding-down bolts passing through the upper two courses of masonry, each of which was 15 inches in thickness.

The six columns were arranged so as to form two clusters, each triangular on plan, and having no other connection at their upper extremities beyond the struts and ties. The two extreme columns, 1 and 4, were each 18 inches in diameter, and inclined inwards at the top 12 inches in their whole height; the other four columns, 2, 6 and 3, 5, were each 15

inches in diameter. They stood in vertical planes parallel to the direction of the bridge, but in those planes 2 and 6 and 3 and 5 were each inclined 12 inches towards each other in their whole height.

Each column was composed of six flanged pipes, connected at their joints with eight screwed bolts, each $1\frac{1}{8}$ inch in diameter. Each triangular cluster was surmounted by a wrought iron box girder L-shaped on plan, taking its bearings upon the three columns; and upon the box girder another wrought iron cellular girder was placed, running in the direction of the axis of the bridge, and vertically under the longitudinal lattice girder of the bridge itself. Upon the upper side of this cellular girder was bolted a massive cast iron plate, a similar plate being also bolted to the underside of the longitudinal lattice girders of the bridge, and between these two plates were placed the cast iron rollers, each 15 inches in diameter and 2 feet in length, upon which the weight of the bridge was carried. This description applies to all the piers, excepting Nos. 31, 35 and 39, in the case of which piers the rollers were omitted, and the longitudinal lattice girders were united to the cellular girders by screwed bolts.

Measuring across the bridge, the cellular girders were equally distant from the centers of the tops of columns 1, 2 and 6, and 3, 4 and 5, and consequently the pressure of the girders of the bridge was borne half by each outer 18-inch column, and one-fourth by each inner 15-inch column.

The three columns forming each triangular group were braced to each other at every joint by wrought iron struts and ties: the struts were horizontal and consisted of two channel irons placed back to back and bolted at each end by two $1\frac{1}{8}$-inch bolts to lugs cast upon the columns. Each of the rectangular openings formed by the columns and struts was stayed diagonally by flat wrought iron bars $4\frac{1}{2}$ inches broad and $\frac{1}{2}$ inch in thickness, the upper ends being connected with the columns by $1\frac{1}{8}$-inch bolts passing through lugs cast upon them, and the lower ends being secured to two sling plates, each $4\frac{1}{2}$ inches by $\frac{5}{8}$ inch thick, by gibs and cotters, and the sling plates being connected with the columns by $1\frac{1}{8}$-inch bolts passing through lugs cast on to them.

The two triangular clusters of columns were braced to each other in a similar manner by struts and ties between the 15-inch columns; that is to say, between columns 2 and 3, and columns 5 and 6. Furthermore, at each joint a wrought iron rod $1\frac{1}{2}$ inch in diameter was introduced horizontally to tie together columns 2 and 5, and columns 3 and 6.

Having thus given a general description of the portion of the bridge which fell, I proceed to consider the strains to which the several parts were exposed under varying circumstances, and how far the structure was capable of resisting these strains. In order, however, to render this Report as brief as possible, and to avoid as far as can be done the introduction of technicalities, I shall here confine myself to a statement of results, but for your information the mode of arriving at these results is annexed in the form of an appendix.

The four forces to which the structure was liable to be exposed were those resulting from changes of temperature, from the weight of the structure itself, from the weight of a passing train, and from the lateral pressure of the wind.

For our present inquiry the strains produced by changes of temperature may be disregarded, and those resulting from the weight of the structure itself, or when loaded with a train, are very easily ascertained. Assuming for the reasons already stated that no additional strain is produced upon any of the piers in consequence of the continuity of the girders, and assuming a train with the weight and conditions of that which fell with the bridge, namely, having a weight, including the passengers, of 120 tons, and supposing it to be placed over one of the piers in the position which would produce the heaviest pressure, I find that the structure alone would produce a compressive strain upon the 18-inch columns of 1.47 tons, and upon the 15-inch columns of 1.06 tons to the square inch; and that with the train over the pier these strains would be increased to 1.84 tons on the 18-inch columns, and to 1.30 tons on the 15-inch columns.

There are so many doubtful elements, the value of which have to be assumed in attempting to determine the amount

of the strains to which the several parts of the piers would be exposed by the action of a powerful wind pressure, that it is impossible to arrive at any positively definite result.

As regards the actual pressure of the wind upon the structure, I have adopted the same views as those taken by Dr. Pole and Mr. Stewart, namely, as regards the lattice girders; for the windward girder I have taken the entire area of the outer face, including the way-beams and rails; for the leeward girder I have taken only the surface above the level of the rails, and I have supposed that the wind would only exercise half its force against this surface, in consequence of the shelter afforded by the windward girder. As regards the train, I have wholly deducted the surface of the lee ward girder which it would shelter, and for the train itself I have only taken half the round surfaces, and have reduced the pressure of the winds by a sixth, that being the extent to which the train would be sheltered by the windward girder.

In the case of the pier I have again adopted the views of Dr. Pole and Mr. Stewart, namely, in supposing that there would be one 18-inch column and three 15-inch colums exposed to the wind, and that the tie-bars and struts would be equivalent to one-fourth of the space—when seen in end elevation—between the columns.

Now, it is a matter of the first importance to determine what wind pressure would suffice to overturn any portion of the train; it is at once evident that the second-class carriage, being the last but one in the train, was the one which had the least stability; and Dr. Pole and Mr. Stewart state that a wind pressure equal to 28½ lbs. upon the square foot would suffice to overturn this carriage. They have, however, assumed that the carriage was empty, whereas the evidence of those who collected the tickets shows that there were eight second-class passengers.

In my own calculation I have assumed the average weight of the passengers at 140 lbs. each, and I have taken into account the vertical pressure resulting from the action of the wind upon the curved surface of the roof, and the conclusion at which I arrive is that the second-class carriage could not have been overturned with a less wind pressure than 35.68 lbs. upon each square foot; and as there is no position in which this carriage could have been placed where it would have been sheltered to a greater extent than between one-seventh and one-eighth of its entire surface, it results that the actual pressure of the wind must have exceeded 40 lbs. on the square foot to have overturned this particular carriage, in the condition in which it was upon the night of the catastrophe, and without regarding any assistance which the couplings might afford in retaining the carriage upon the rails.

The next subject that I have investigated is the effect which the wind would have in lessening the weight of the superstructure upon the windward rollers, and in increasing the same upon the leeward ones, and the results are shown in the following table:

	Without any wind.	With pressure of wind equal to			
		10 lbs.	20 lbs.	30 lbs.	40 lbs.
	lbs.	lbs.	lbs.	lbs.	lbs.
Without any train:					
Pressure on west rollers .	322,450	300,120	277,930	255,670	233,410
Pressure on east rollers...	322,450	344,710	366,970	389,230	411,490
	644,900	644,900	644,900	644,900	644,900
With a train:					
Pressure on west rollers ..	427,615	399,205	370,795	342,385	313,975
Pressure on east rollers...	427,615	456,695	485,775	514,855	543,935
	955,230	855,900	856,570	857,240	857,910

The slight increase which will be observed in the total pressure upon both rollers with an increased wind is owing to the vertical pressure resulting from the action of the wind on the curved roofs of the carriages.

These pressures upon each set of rollers are, as I have already explained, equally divided between one 18-inch and two 15-inch columns; these pressures are, however, still further modified by the horizontal pressure of the wind acting against the exposed surfaces of the superstructure, pier and train, but to what extent it is very difficult to determine.

If for a moment it is assumed that the pier may, by virtue of the system of bracing, be considered as a rigid structure, and the effect of the bolts in holding down the columns be disregarded, then the wind pressure required to overturn the structure, about the east 18-inch column as a center, would be 36.38 lbs. without any train, and 32.69 lbs. on the square foot, with a train over the pier.

But, unfortunately, the piers must have been very far from being rigid structures, in consequence of the imperfect manner in which the struts and ties were connected with the columns. The struts consisted of channel irons, placed back to back with the lug of the column between, and connected therewith by two $1\frac{1}{8}$ inch bolts at each end; the holes for the bolts were cast $1\frac{1}{4}$ inch in diameter, and being rough and larger than the bolts, and the ends of the struts having no bearing surface to abut against, the struts themselves were only retained in their positions by the pinching action of the bolts. But the security thus afforded must have been very slight, because, owing to inequalities in the surfaces of the lugs themselves, and to the fact that in some cases the holes in the struts had been roughly enlarged with a blunt tool so as to leave a burr, the actual bearing surface of many of the struts against the lugs was very small.

As regards the flat ties, when the structure was first erected they were tightened up by means of gibs and cotters, but, owing to the slots in the bars against which the gibs and cotters bore being rough, and the gibs and cotters also roughly forged, and, further, owing to the holes cast in the lugs not being cylindrical, and to a screwed bolt being used to secure the ends of the ties instead of a pin, the real bearing surface was exceedingly small, and a comparatively slight strain would suffice to crush the edge of the hole in the lug into the thread of the screw.

In reference to the tie bars it should also be observed that the bearing surface of the gib against the slot in the bar was quite inadequate, for while the area of the section of the bar exposed to a tensile strain was 1.625 square inches, the bearing surface of the gib being in compression should have had an area of 1.86 square inches, whereas it had only a surface of 0.375 square inches, or about one-fifth of the strength of the bar.

From these circumstances it would result that a lateral pressure against the columns would produce movement in the struts and ties, resulting in the latter becoming slack. And this movement actually did take place; in some of the tie bars still standing I found packing pieces of iron $\frac{1}{4}$ inch in thickness had been introduced between the gibs and cotters, and on inquiry I learned that these had been introduced from time to time since the opening of the bridge.

From the accounts which have been furnished to me it appears that about 150 of these packing pieces were inserted in the ties between the middle of October, 1878, and the time of the bridge falling, and that the necessity for them arose before the bridge had been opened five months. This circumstance clearly shows that there must have been a considerable racking movement in the piers under the united action of passing trains and wind, and I cannot but consider points to the primary cause of the disaster.

For the slackening of these ties and struts means the removal of that condition upon which alone the power of the structure to resist being overthrown by a lateral pressure depends. And it is easy to conceive that a storm of the violent character of that of the 28th of last December, would produce such movements, in the connections of these struts and ties with the columns, as would render the columns unable to sustain the additional weight of the train and the lateral pressure of the wind.

An examination of the ruins of pier

No. 32, being that over which the train was situated when the structure fell, indicates that the columns doubled up about their joints as the lower lengths of the westward 15 inch columns were pushed over to the west, or in the reverse direction to that in which the rest of the structure fell. A similar action in pushing back the westward columns is seen in piers Nos. 36, 39, and 40.

The present state of piers Nos. 29 and 31 affords conclusive proof of a weak point existing in the structure at the time of the overthrow in each of those piers, namely, in pier No. 29 at the level of the top of the second tier of columns, and in pier No. 31 at the top of the lower tier; for the strain at the point of fracture was, in the former case, only five-sevenths, and in the latter case only six-sevenths, of the strain at the base of the pier, while theoretically the strengths of the pier at the base and at the points of fracture were the same. It is clear, therefore, that the power of resistance of these two piers had been reduced at the points of fracture in the case of pier No. 29 to the extent of two-sevenths, and in the case of pier No. 31 to the extent of one-seventh of their normal power of resistance.

Considering that the columns are 76 ft. in height, that with a wind pressure of only 20 lbs. on the square foot, a pressure of 337 tons will be thrown upon the eastward 18 inch column at the time of the passage of the train, and that a horizontal pressure of $37\frac{1}{2}$ tons is acting against the top of the column, it is easy to conceive what must have been the inevitable consequences of any slackness on the part of the ties.

It is also necessary to point out that owing to the double angle which the ties, by which the 18 inch columns are braced, make with the direction of the force tending to overthrow the structure, the efficiency of these ties is reduced in the proportion of 1 to 2.73, or to little more than one-third of their full strength, and that any elongation or movement of the ties would allow of nearly three times that movement in a horizontal direction in the point of the column to which they were attached.

There are also other circumstances in connection with the construction and workmanship of the bridge which undoubtedly contribute to the catastrophe.

The mode of securing the holding-down bolts was not satisfactory, as they had no anchor-plate or bearing at their lower extremities, but were merely inserted in a hole drilled through the two 15 inch courses of stone, and were then run round with cement, and, as the angle of taper of the conical head was only $6\frac{1}{4}$ degrees, it is evident that a very slight compression of the cement would allow of a considerable movement in the bolt; some of these bolts have evidently yielded as much as 8 inches in screwing down the base-piece at the erection of the bridge, and in one or two cases the stones have been burst by the wedge action of the conical head. It would have been better also if they had been carried to a greater depth, so as to have had a greater weight of masonry to be lifted instead of trusting to the adhesion of the cement, which appears to have been very slight, partly in consequence of the smoothness of the sawn face of the stone, and partly, I imagine, from the stone having been dry when set. In many cases the cement has parted from both stones, forming a thin detached sheet of large dimensions. In many cases also the nuts at the upper ends of the bolts have a very imperfect bearing upon the base-piece.

Passing on to the columns, it is apparent that many of them have blow-holes of considerable size, which have been filled in with a composition of resin and filings; sufficient care does not appear to have been taken to keep the cores from shifting, or in properly adjusting the upper flask, and as a consequence there are many instances of a considerable difference in the thickness of metal on opposite sides of the columns; in some cases the metal on one side being only $\frac{5}{8}$ inch, and on the opposite side $1\frac{3}{8}$ inch, or a difference of $\frac{3}{4}$ inch; and as is usually the case when the upper side of a casting is thin, the metal becomes chilled, and has accumulations of scum and air which very much deteriorate from the strength of the metal.

The mode of attaching the ties to the columns by means of lugs was evidently insufficient, as in almost every instance the lugs have been torn away, it

is difficult to believe that the burning on of defective lugs in the manner described by the witnesses examined at Dundee could have been sanctioned by any person who had the intelligence to understand that the whole security of the structure depended upon the strength of these lugs.

I consider that the mode of connecting the columns at the flange joints was also in some respects defective, the bolts being $\frac{1}{8}$ inch less in diameter than the hole, and the flanges being separated in some cases as much as $\frac{3}{4}$ inch, the bolts could not act as steady-pins, and as in several cases there was no spigot on either of the pipes, there was nothing but the pinching of the bolts to prevent the columns from shifting, and there are evidences that some of them did so shift at the time of the catastrophe.

I have not regarded the concrete as having added in any way to the security of the structure, otherwise than in its increasing the weight of the columns, and so increasing the moment of stability of the pier; and my reason for taking this view is that the concrete was so unequal in its quality that no dependence could be placed upon its being of proper strength in the place where strength was required.

Before leaving the columns, I should observe that some of the flanges were so imperfectly faced that the only portions of the metal in contact was a strip of about $\frac{5}{8}$ inch round the margin of the flange.

In conclusion, I would sum up by the statement that, in my opinion, the base of the pier was too narrow, occasioning a very great strain upon the struts and ties, that the angles at which the latter were disposed, and the mode of connecting them to the columns, were such as to render them of little or no use, and that the other imperfections which have been pointed out lessened the power of the columns to resist a crushing strain; I consider that the yielding of the struts and ties was the immediate cause of the disaster, but that the other circumstances stated contributed to it.

It is only due to Sir Thomas Bouch, to his assistant, Mr. Thomas Peddie, to Mr. Noble and the officials of the North British Railway, to say that they have afforded me every facility for making the most thorough and searching investigation.

ON THE PHYSICAL ASPECTS OF THE VORTEX-ATOM THEORY.

By S. TOLVER PRESTON.

From "Nature."

In all attempts to arrive at a satisfactory conception of the ultimate constitution of matter, the grand difficulty has hitherto been to reconcile the proved indestructibility of the atom with its capacity for executing vibrations, as demonstrated by the spectroscope. The ancients, by assuming the atom to be *infinitely hard*, attempted in this way to get over the difficulty of indestructibility (or indivisibility), but thereby debarred all means of conceiving the "*elasticity*" of atoms, or their known powers of taking up vibrations of different periods.

When we consider the immense difficulty that there must have been in conceiving how an atom could be elastic (*i. e.*, how its parts could be capable of free motion) and yet its parts be incapable of separation from each other, we may well excuse the attempt to explain indestructibility by the assumption of the quality of *infinite hardness*, unsatisfactory though it might be.

It is evident that if we are to renounce all idea of occult qualities of "elasticity," hardness, indivisibility, &c., and purpose to explain the facts without recourse to postulates, we must assume the material substance of which our atoms are to be formed, to be itself entirely without any positive qualities, *i. e.*, to be without elasticity, hardness, rigidity, &c., and therefore to be freely penetrable in all parts, or perfectly passive and inert. This is the perfect liquid of the vortex-atom theory. There may be some who would say that it is difficult to conceive

of such a liquid. On the contrary, we venture to be able to prove that such a liquid *always is conceived of* whenever a liquid is thought of. Thus, does any one in conceiving of a liquid (water, for instance), regard the liquid as consisting of solid (*i. e.*, more or less rigid) portions of matter sliding over each other [as we might conceive solid masses sliding past or through each other on a magnified scale]; and yet this is truly what the liquid (composed of molecules) is in the actual fact. In short, it is not a "*liquid*" at all. Yet we conceive of it as *liquid*, *i. e.*, freely penetrable in all parts. We therefore contend that a perfect liquid (or true liquid) is what is *always* conceived of, and therefore that there can be no difficulty in regard to the conception of the true liquid that forms the basis of the vortex-atom theory.

In the next place, it is an obvious condition to any consistent conception of matter that matter must possess *extension*,* or occupy space, *i. e.*, so that two portions of our liquid cannot occupy the same space at the same time. If, therefore, the liquid fills all space, it must be incompressible. This is, therefore, not an arbitrary postulate.

The next question naturally suggesting itself would be, how are portions of such a liquid to attain the properties that we recognize in atoms? We venture to think it will be conceded as evident that the only *conceivable* way (if it be admitted that the result is attainable at all) is through *motion* [for this is the only conceivable way in which the liquid can be affected.] The further inquiry would therefore be, what would be the *character* of this motion? Now, in order to fulfill the condition that the atom itself can be brought to rest without losing its properties as an atom, it is evident that the motion of the material forming it must take place in such a way that the atom can remain in one spot, or be to our senses at rest, *i. e.*, the material of the atom, although in motion, must not deviate from one spot. We ask if there is any other *conceivable* form of motion than *rotary* motion that would fulfill this condition? Hence the necessity for looking to *rotary* motion as the basis of the properties of the atom. In the next place, a portion of material in rotation must rotate about an *axis*. If the ends of this axis were exposed, we should have two points *at rest*, which would forfeit the condition of *motion* being the essential basis of the external qualities of our atom. The question is, therefore, how is a portion of material to be in rotation about an axis, and yet not expose the ends of the axis? The only *conceivable* answer (as we think will be admitted) is that the rotating portion of material must have the form of a closed ring, or complete circuit, so that the axis has no ends. We therefore think it may be said beforehand that conceding that the problem of the atom can be solved at all (or if it be conceded that a fact can exist solely in virtue of the explanation that underlies it) then the problem could only *conceivably* be solved under the fundamental conditions above developed, *i. e.*, under the condition of a portion of material (having no positive properties in itself) *rotating* in the form of a *closed circuit.*

This (as is well known) is what has been found to satisfy the conditions for the atom by the application of mathematical analysis (without, apparently, that object having been in view at all), and in a manner the most remarkable in its completeness. It appears possible, in view of the above considerations, that a profound and competent thinker who had devoted himself to the subject might have arrived, even before the mathematical analysis had been applied, at the *sole conceivable* physical conditions that in principle could satisfy the problem of the atom (admitting the *existence* of the solution); but the mathematical analysis can, of course, alone make the fact of the solution apparent to us. It is related in the article on "The Atomic Theory of Lucretius" (*North British Review*, March, 1868) that Hobbes had arrived at the fundamental idea that the *rotation* of a portion of material must be the basis to the solution of the problem of the "elasticity" of the atom, without having applied any mathematics.

The difficulty of the mathematical side of the vortex-atom theory is curiously contrasted with the simplicity of the physical side of the theory. If we suppose a cylindrical bar of india-rubber to be rotated about its longitudinal axis,

*The quality of extension may even be regarded as included in the definition of matter.

and the bar (still rotating) to be bent round into a ring shape and the ends joined (the rotation of the material of the ring being always continued), then this may serve to illustrate in a simple way the motion of the material forming the vortex-atom. It is here apparent that the material of the india-rubber ring (in our illustrative case) may be in rapid motion while the ring itself preserves a fixed position in space. It would seem to be a pity if a spurious mystery should be allowed to envelop this subject, which is unworthy of it, in view of the simplicity of its physical basis. No one doubts the difficulties that had to be surmounted on the mathematical side of the theory, but there is all the more reason on that account that the extreme simplicity of the physical side of the theory should be duly appreciated, and unnecessary obstacles not be thrown in the way of its adoption. The tendency to invest physical subjects with a halo of the occult [possibly partly attributable to the unfortunate introduction into physical science of the spiritualistic conception of "*force*"—in the sense of an action across space without the intervention of matter] has probably done more to hinder progress than any real difficulties.

We shall simply state the facts of the mathematical analysis here, our business being more particularly with the physical side of the theory. First it is shown by incontrovertible mathematical proof that a portion of material having the motion above described possesses all the qualities of a *solid*. It is at the same time "*elastic*," or capable of changes of form when acted on through impact by other atoms —always tending to return to its symmetrical form when removed from constraint. It is, moreover, proved to be competent to execute vibrations of definite periods which it is the function of the spectroscope to measure. The atom thus constituted is demonstrated to be incapable of being divided or severed by the collisions of other similar atoms against it, and *since this is the sole means of acting upon it*, the long-standing riddle of indestructibility is thus simply solved, without the necessity for any postulate of *infinite* hardness. As the degree of hardness merely depends on the velocity of rotation of the material, it follows that the vortex-atom may possess any degree of hardness. Indeed, if we imagine the atom to be magnified up to visible scale, it might be conceived to be harder or more rigid than a ring of steel of the same dimensions, since the hardness of steel is limited by the resistance of the component atoms to displacement.

The centrifugal tendency of the rotating material of the vortex-atom is controlled by the exterior incompressible liquid, and as there is no friction [there being no ultimate solid parts in the rotating liquid to "catch" against the inclosing fluid walls], the rotating portion therefore glides smoothly over the incompressible liquid that surrounds it like a pipe. Indeed, if we leave out of our conceptions the portion of rotating liquid, then the surrounding liquid actually forms a complete pipe in the form of a closed ring. If the liquid in the pipe were to fly out, a temporary void would be formed in it, which is impossible in a liquid that already occupies all space. An idea of the resistance of such a rotating portion of material to bending may be got by attempting to deflect a gyroscope or spinning-top.

In the old idea of *infinitely* hard atoms there were difficulties in forming a satisfactory conception of what took place at the collision of two such atoms, or how the rebound could effect itself (consistently with the conservation of energy). The following difficulty may also be mentioned: Since two such atoms are supposed to be absolutely hard or unyielding, the area of contact at the collision would necessarily be merely a mathematical point. Now the intensity of a given pressure on a surface is inversely as its area; and accordingly, since the area is here a mathematical point (or infinitely small), the pressure attendent on the collision of the two atoms would require to be *infinitely* great. It may be a fair question how even an *infinitely* hard atom is to withstand the disintegrating influence of an *infinite* pressure.*

In the case of the vortex-atoms they

* The fact of two such infinitely hard atoms being stopped in an infinitely short space at collision [for there is by hypothesis no *gradual* yielding] would by itself entail an infinite pressure *in addition* to the infinite pressure due to touching at a mathematical point.

yield somewhat at collision (without change of volume, of course), whereby the encounter takes place over a surface (not a point); and they rebound in virtue of their elasticity, due to the motion of the material forming them.*

There would seem to be a view to a certain extent prevalent that the vortex-atom theory essentially alters the basis of the old-established ideas of solid indestructible atoms surrounded by space in which they can freely move, to which so many have accustomed their conceptions, and worked upon to the successful discovery of new facts, and which ideas, therefore, they might be reluctant to abandon. This step, however, is not required at all. The main purpose of the vortex-atom theory is to explain the "*elasticity*" of atoms, retaining substantially everything else appertaining to the old atomic theories, merely removing the unsatisfactory postulate of *infinite* hardness. For since the perfect liquid (outside the portions of it that form the atoms) opposes no resistance whatever to the passage of the atoms through it, or it is impossible to act on the exterior liquid, it is therefore in this respect as if a void existed outside the atoms. It is desirable, however, to note that the vortex-atom theory involves essentially the *existence* of the liquid outside the atoms, which performs important functions, but since this exterior liquid is proved to be incapable of appealing to our senses in any way, it therefore *in that respect* may be said to play the part of a void. The exterior liquid of the vortex-atom theory corresponds to the void space of the theory of Lucretius. With the above qualification, therefore, it may be allowable, when we are not specially dealing with the problem of the constitution of the atom itself, to leave out of our conceptions the presence of the exterior liquid; that which we call "matter" being the atoms, and not the exterior liquid. In all practical problems of physics, therefore, (apart from the problem of the constitution of the atom), we may properly regard the atoms simply as *elastic* indestructible solids moving freely in space. Moreover, since the motion of rotation of the material of the atom is incapable of transference, and cannot appeal to our senses, and this motion does not in any way alter the position of the atom in space [but it is exactly as if the atom *itself* were at rest]; we can, therefore, if we like, leave this rotary motion out of our conceptions, merely keeping in view the result produced by the rotation, viz., the sharply-defined elastic indestructible solid thereby formed. The function of the modern theory is accordingly not to destroy the atomic theory of the ancients, but rather to support it, by explaining *how* such indestructible bodies can exist, without recourse to the unacceptible postulate of *infinite* hardness. This old theory of the atomic constitution of matter was really too firmly grounded on reason and observation, as that one should suppose that its very foundations could be shaken.

Broadly and generally, therefore, in practical problems of physics, the essential points to recognize are that atoms—or molecules—are elastic indestructible bodies, capable of rebounding from each other without loss of energy, and of executing vibrations of fixed periods. The existence of this *elasticity* is a fact so definitely proved by the spectroscope, which actually measures the *number* of vibrations executed per second by molecules, that it would become a question to *explain* this fact, even if the vortex-atom theory had not been proved to be capable of affording a complete explanation of it. Indeed, not only is the theory *capable* of doing this, but the vibrating capacity possessed by molecules is shown to be a *necessary* consequence of the theory, so that, therefore, the fact might even have been deduced *à priori*. Considering how enormously difficult it appeared to account for this fact at one time, or how impossible it seemed to reconcile the mobility of the parts of a molecule with the inseparability of these parts by the most energetic collisions, and how an explanation of this fact was at one time sought after, it would appear not too much to expect that those who hesitate to accept the explanation given by the vortex-atom theory, should endeavor to define for themselves wherein their grounds of objection lie. For if the explanation of a fact be admitted to

* The rebound of vortex-atoms may be illustrated (as is known) roughly by the rebound of two smoke-rings from each other, or by the rebound of vortex-rings in an ordinary (imperfect) liquid.

be substantially complete, it would be at least unreasonable to look for more. The question might also suggest itself as a fitting one to any impartial inquirer, whether any other solution to the problem of the constitution of the atom is in principle *conceivable*, or whether [as in the case of many other physical problems, the constitution of the ether, for instance] but *one* solution is conceivable (or we have no choice at all). It cannot be said at least that the theory of vortex-atoms, or its physical side, is not *simple*, dealing as it does with the mere *rotation* of a portion of matter.* It is so far recognized that simplicity of the means to the end is a general characteristic of nature. No doubt there may be difficulties in the mathematical development of the subject; but if an atom be once proved to be elastic and indestructible, that fact surely goes very far to supply all we want for the practical applications of the theory. Of course there may be some refinements that may present great mathematical difficulties. For instance, Prof. Tait in his work, "Lectures on some Recent Advances in Physical Science," mentions a case where a vortex-ring is supposed to come into collision with another in such a way that the motion is not symmetrical in relation to the axis, and it is cited as an almost insurmountable difficulty to find what exactly takes place (in regard to particular vibrations or rotations developed, possibly). But one might ask, is it necessary to know this for practical problems of physics? We may know broadly that vibration or rotation is developed, and if so (apart from the abstract interest of the question), do we want to know precise quantitative details for practical purposes? It might for example be extremely difficult to determine mathematically the exact deformation or changes of form (vibrations, &c.) that a steel ring underwent when thrown against the hard surface of an anvil; but the practical question is, do we want to be acquainted with this for any ordinary problem that might occur, or in order to appreciate the general principles of impact, for instance? So in the case of vortex-atoms, no doubt many instances might be cited when it would be difficult to ascertain precise results, but the practical question is, Does this prevent our applying the theory to ordinary physical problems,* or to dynamical phenomena involving questions of principle? For possibly it may not be necessary to know the exact vibrations developed at a collision (for instance), provided we recognise the fundamental point that energy is conserved, and that the atoms can rebound from each other like perfectly elastic solids. It would be a pity if the mere *difficulty* of arriving at precise mathematical results of a refined character, should be mistaken by some for *mystery*, or it would be a thing to be regretted if there should be any tendency to throw a veil of the "occult" over what in its *physical basis* (at least) is very simple, this procedure only hindering progress and rendering a closed book what might be a most interesting branch of mechanics.

The investigations regarding the perfect liquid have already (as is known) thrown some important light on the important practical question of the resistance of ships. Mr. Froude has especially devoted himself to these inquiries.

*It would seem to be thought by some that the primary *ring* form of the vortex-atom involves something complicated in it. I venture to think that this is only one of those first impressions, which will disappear on reflecting on the subject. First, many facts strongly indicate that matter possesses a more or less *open* structure (or is highly porous). These ring molecules would give matter an open structure. It would seem also independently probable that a molecule should have no more material in it than is essential to give it a certain amount of *extension*, or to make it occupy a certain range of space. Why should we suppose that waste or apparent superfluity of material in a molecule that a solid structure throughout would involve? Does not this violate one of the fundamental principles of large scale architecture, where superfluity of material is recognized as one of the worst faults, and mechanical principles are admittedly independent of scale? The *ring* shape for the atom is evidently the simplest elementary form to satisfy the condition for the maximum of *extension* combined with the minimum waste or expenditure of material. In view of these considerations, the ring-shape, the primary form required by the vortex-atom theory, may seem in itself independently probable. Indeed, it seems a remarkable fact that the main conditions inevitably led up to by this theory by a rigid mathematical process, are precisely those that independent observation support, (1) the *indestructibility* of the atom, illustrated by chemistry and numerous facts, (2) the *elasticity* of the atom, proved by the spectroscope, (3) the *open* structure of the atom, in harmony with the transparency of some bodies to light, the free passage of the magnetic disturbance through all bodies, and numerous other facts—not to mention the physical theory of gravity. In short, it would appear that it would be necessary to infer the *existence* of indestructible elastic atoms of open structure, even if the vortex-atom theory (which *explains* this fact) had not been invented.

*The writer himself has seen from German comments on Prof. Tait's work, that the passage above referred to [German translation] has been regarded by some as if the difficulty there mentioned were of such a nature as to prevent the practical adoption of the theory.

The old idea that a ship (or more correctly a totally immersed body, such as a fish) encountered a mysterious resistance in addition to the mere friction of the molecules of water on its sides, is now known to have been a pure delusion. If it were not for the fact that the water consisted of molecules or ultimate rigid parts which are caught and put in motion by the rough sides of the ship, there would be demonstrably no resistance at all. Hence the absence of resistance in a true liquid (which is not formed of ultimate rigid parts or molecules). If the molecules or ultimate rigid parts of which an ordinary "liquid" consists, were to be liquefied, a being immersed in it would (if conscious) imagine he was surrounded by empty space.

The late Prof. Clerk Maxwell in a review of the theory of vortex-atoms in the "Encyclopædia Britannica" for 1875, under the word "*Atom*," makes the following remark on the theory:

"But the greatest recommendation of this theory from a philosophical point of view, is that its success in explaining phenomena does not depend on the ingenuity with which its contrivers 'save appearances' by introducing first one hypothetical force and then another. When the vortex-atom is once set in motion, all its properties are absolutely fixed and determined by the laws of motion of the primitive fluid, which are fully expressed in the fundamental equations. The disciple of Lucretius may cut and carve his solid atoms in the hope of getting them to combine into worlds; the follower of Boscovich may imagine new laws of force to meet the requirements of each new phenomenon; but he who dares to plant his feet in the path opened out by Helmholtz and Thomson has no such resources. His primitive fluid has no other properties than inertia, invariable density, and perfect mobility, and the method by which the motion of this fluid is to be traced is pure mathematical analysis. The difficulties of this method are enormous, but the glory of surmounting them would be unique" [p. 45].

Much misapprehension would seem to exist in regard to the physical side of the theory, especially in Germany,* where the mathematical investigations out of which it sprung, had their origin. Some appear to be unable to conceive how motion should take place in a material substance continuously filling space, losing sight of the fact that the liquid outside the atoms plays the part of a void (in so far as it cannot appeal to our senses)—or it is only the atoms that affect our perceptions. Others fail totally to appreciate the simplicity of the physical side of the theory, and seem to think it involves arbitrary postulates, whereas the main peculiarity of the theory is its freedom from positive assumptions, inasmuch as the theory evolves all the properties of matter out of the *motion* of a material substance, which without this motion has no positive qualities at all, and could not appeal to our senses. The fact seems to be overlooked that if we renounce the occult quality of *rigidity* in the atom, we have no other resource than a *liquid* (*i. e.*, a substance without rigidity). Much of the misunderstanding on the subject may no doubt be due to the scarcity of the literature relating to it, and the extreme brevity and absence of detail or attempt to assist the conceptions regarding the physical side of the theory. This want the author himself has much felt, and having been at considerable trouble to render clear his own conceptions as far as he could, he has thought that the result of this analysis might not perhaps be unacceptable in the form of a paper on the *physical aspects* of the theory.† For there are no doubt many investigators in the paths of natural science who may find some difficulty in realizing the physical basis and real bearings of the theory, and who nevertheless take a rational interest in the solution it is capable of affording to some of the greatest difficulties of molecular physics. The whole structure of physics may be said to rest upon a *molecular* basis, and therefore the im-

*The writer has had personal experience of this, partly through correspondence, and partly through the literature relating to the subject. Quotations from the writings of Prof. Zöllner especially seem to show a want of appreciation of the *physical* points of the theory at their true value and significance.

†As regards sources of information as to the vortex-atom theory, the following may be mentioned: Sir William Thomson, "On Vortex-Atoms," *Phila. Mag.*, July, 1867. Prof. Clerk-Maxwell, article "Atom," *Encyc. Brit.* 1875. The theory is dealt with to some extent in a popular manner in an article on "The Atomic Theory of Lucretius," *North British Review*, March, 1868, also by Prof. Tait, in his work "Lectures on Some Recent Advances in Physical Science."

portance of a right view of this basis cannot be over-estimated. The old theory of *perfectly rigid* molecules put an immense difficulty in the way of the development of physical results upon such a groundwork. A theory of *elastic* molecules therefore becomes of the utmost importance as a practical working hypothesis, and the accordance with observation of new results predicted from this hypothesis as a basis, will then form additional confirming illustrations of its truth. The removal of any misunderstandings that might be obstacles in the way of the use of the vortex-atom theory as a working hypothesis becomes, therefore, a point of considerable importance. Those more especially who have handled the spectroscope and viewed the exquisite precision of its results, become impressed with the *certainty* of the groundwork upon which their molecular studies are based, and no less imbued with the conviction of the existence of that *explanation* that forms the basis of the facts that are recorded with such unfailing accuracy.

REPORTS OF ENGINEERING SOCIETIES.

The regular meeting of the Engineers' Club of Philadelphia, was held on Saturday evening, May 15th, Mr. Frederic Graff, President, in the chair. The Committee on Improvement in Land Surveying in Pennsylvania, was announced as follows: Messrs. Chas. E. Billin, Chairman; Saml. L. Smedley, L. M. Haupt, W. C. Cranmer and John H. Dye. Mr. Arthur Sheafer read a paper on the Olean, Bradford and Warren and the Kendall and Eldred Railroads, in the oil regions of McKean Co , Pa. The O. B. & W. R. R. is 23 miles in length, from Bradford, Pa., to Olean, N. Y., reaching a height of 960 feet above Olean or 2398 feet above tide. Gauge, 3 feet; rails, 35 to 40 lbs. per yard; maximum grade, 185 feet per mile, two miles being at a grade of 185 feet per mile; maximum curve, 30 deg., 350 feet in length on trestle 25 feet high. The road was commenced in November, 1877, and in 60 days trains were running between the termini.

The K. & E. R. R. is 18¾ miles long from Bradford to Eldred, McKean Co. Gauge, weight of rails and maximum curves, same as O. B. & W.; maximum grade, 136 feet per mile; summit. 656 feet above Eldred or 2099 feet above tide. Crosses the Alleghany River on Howe truss bridge of two 90 feet spans. Its total cost, including equipment, was $150,000. In August, 1878, or 90 days after running preliminary lines, trains were running from Bradford to Eldred.

Mr. Neilson gave some notes on the Chicago & Tomah R. R. (narrow gauge), on which 20 lb. rails were used, even on 25 deg. curves, and trains of seven cars, each of 13 gross tons wt., were run.

Mr. A. R. Roberts announced a recent trial run on the Bound Brook R. R , by the single driver engine, of $89\frac{3}{10}$ miles, in 97 minutes with four cars, and returning in 96 minutes with five cars. One run of 27 miles was made in 26¾ minutes. No heating of the machinery was observed. Mr. J. J. DeKinder illustrated the French method of sub-marine diving, which is a great improvement on the old method, with heavy helmets, etc. The apparatus is composed of a horizontal cylinder, surmounted by another cylinder at right angles to it, with a rubber cap. The lower cylinder is connected with the air pump by a tube, and the upper by another tube with the diver's mouth. A spring clamp is worn on the nose, the tube held in the mouth, and the apparatus worn on the back like a knapsack. By the action of valves, the air is circulated as the diver breathes, and he is encumbered with no other apparatus. His loaded shoes do not interfere with ease of motion, and he can rise at will. As little diving is done in winter, the temperature of the water is not an objection to its general use.

Mr. Freeland explained formulæ for a linkage connection for a valve motion. Mr. L. M. Haupt read an extract from a petition to Congress on river improvement.

The last meeting for the season, of the Engineers' Club of Philadelphia, was held on Saturday evening, June 5th, 1880—Mr. Percival Roberts, Jr., Vice President, in the chair—Mr. David Townsend read a paper on "A New Method for the Quantitative Determination of Combined Carbon in Cast Iron and Steel," and exhibited the apparatus for this purpose.

Mr. J. J. deKinder read a description of an Improved Apparatus for handling dredged material, designed by Mr. A. E. Hall, of Boston. By means of this apparatus dredged material can be conveyed from the dredging machine to the shore with equal facility at any stage of the tide, and without any intermediate handling of the material. The apparatus was illustrated by two large photographs.

Mr. Howard Murphy read, on behalf of Mr. J. Milton Titlow, a paper on "The Turn-table of Penrose Ferry Draw Span, Philadelphia."

The bridge that is swung by means of this turn-table is a through wrought-iron roadway bridge, 21 feet between centers of trusses and without footways.

The trusses are of the double cancel Pratt system, with inclined end posts and 411 feet between lower centers thereof, or about 415 feet over floor ; the depth at ends is 28 feet and 38 feet at center, the panel lengths being 15 feet except that at center which is 21 feet.

The four posts are equi-distant, transversely and longitudinally of bridge, and the center line of the drum passes through each of them, it being 30 feet in diameter and 6½ feet in height.

The turn-table is built so that it may be either rim or center bearing, but at present is used as the latter.

The weight upon the four center posts is carried to the center bearing by means of four

wrought-iron plate-girders 6 feet in depth and 30 feet long, which act as cantilevers and are placed side by side 3½ feet apart in two pairs, and at right angles; their ends being riveted to drum under posts of trusses. One pair of girders is set some three inches higher than the other, the plates of their top flanges being continuous across and through their intersection.

Within the box or space formed by the intersection of these girders stands the cone or pivot, the point of which is about on a level with their top flanges; above this the Sellers Box with 125 lineal inches of rolling and 56½ square inches of sliding surfaces, and upon this the carrying plate or table.

From this heavy plate the girders are suspended from their lower flanges by means of eight bolts, and by the nuts thereon the bridge may be raised or lowered to make the table either rim or center bearing.

Thus by simple construction with the same kind of material the weights are transferred as desired.

The live ring is formed of 51 wheels 16 inches in diameter and 7 inches tread.

The weight of the bridge is 300 tons, when closed and loaded 576 tons, weight of turntable, tracks, etc., 79 tons.

Upon the two segments of the turn-table outside of the trusses are placed on either side the Engine, Boiler, etc.

On account of the small space the engine stands parallel with the bridge, and the power is communicated by means of friction wheels and bevel gearing to two driving pinions on opposite sides of the rack, and to the two out end sets of screws, cams, etc, by means of which the ends are brought to bearings.

Mr. Rudolph Hering discussed the subject of the pollution of the Delaware and Schuylkill Rivers, and also, the intercepting sewers proposed by Mr. Darrach. From statistics covering the population living on the different drainage areas, the sewer connections and water closets, it is estimated that the sewerage of about 290,000 persons daily reaches the rivers, of which 167,500 drain into the Delaware, 119,500 into the Schuylkill below the dam and about 8,000, including the equivalent for the Manayunk Mills, into the river above the dam.

Comparing these quantities with the minimum flow of the two rivers after a long drought, it appears that at such times, the Delaware water will not be as wholesome as the Schuylkill, but that both are likely to be polluted above the admissable standard. How little use is made of the water carriage system may be seen from the fact that there are only 33,100 water closets in the city for 150,000 houses. It is estimated that nearly 500,000 persons make no use of the sewers, but use privy wells, which are periodically cleaned, but allow over 6 million cubic feet of fluid yearly to drain into the soil.

Intercepting sewers must soon carry this filth away from the city and its drinking water. Four-fifths of the drinking water is pumped from the Schuylkill and one-fifth from the Delaware.

Mr. Darrach's sewer to protect the Fairmount pool runs across the city into the Delaware, between the Kensington and Frankford pumps. It is also a mile longer than if it discharged below the Fairmount Dam, where no water is pumped.

Mr. Hering then described a system of intercepting sewers which he thought suited better our demands and was less expensive.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The May Number of the transactions contains the following papers:

No. 191—On the Variation Due to Orthogonal Strains in the Elastic Limits in Metals, by Robt H. Thurston.

No. 192—Experiments with Appliances for Testing Cement, by Alfred Noble.

No. 193—Design and Construction Table for Egg-Shaped Sewers, by C. G. Force, Jr.

No. 194—The Preservation of Timber, by J. W. Putnam.

IRON AND STEEL NOTES.

THE HISTORY AND MANUFACTURE OF STEEL.—Professor Alex. B. W. Kennedy, of University College, London, delivered last week two lectures on this subject at the Edinburgh Philosophical Institution. In the first lecture he spoke of the great change which had recently come about in the meaning of the word steel. For centuries, he said, steel had been a material of use chiefly for weapons, tools, and instruments where its extreme hardness and durability were its most valuable characteristics. But since 1830, when wrought iron first began to be used in large structures of any kind—ships, bridges, and so on—engineers had rather turned their attention to some of the other qualities possessed by steel, and had tried to find a material having the great strength of hard steel without its want of ductility. Such a material we now had in the so-called "mild steel" produced by the Bessemer and Siemens and Siemens-Martin processes—a material of enormous value in construction, but in reality often rather a pure iron than a steel proper. After a short description of some of the Eastern and other primitive methods of making steel, Professor Kennedy described in some detail the present method of making cast or crucible steel at Sheffield. He gave a short sketch of the life of Benjamin Huntsman, the Quaker inventor of the cast steel process in the early part of the last century, and of the ruse by which his brother steel makers succeeded in finding out his secret after their kindly attempt to prohibit the exportation of his steel—which they had at the same time declined to use themselves—had come to grief. He then sketched the various modifications of Huntsman's process now in use, described the leading characteristics of the materials produced by them, and concluded with a brief mention of some of the other steel-making processes, producing puddled steel, Uchatius steel, &c. In his second lecture he began by describing the common method of making wrought iron by "puddling," a process which he characterized as probably the roughest and most cruel of all metallurgical processes, whilst its rival—the Bessemer process—was the grandest and most beautiful. The processes of piling and rolling

bar iron were briefly described, in order to show the nature of the shortcomings in them, which were the causes of the great existing defects in wrought iron—defects of which the absence was essential to the development of the best properties of "mild steel" or ingot iron. The Bessemer process was then described in some detail, and the lecturer then went on to give an account of the "open hearth," or Siemens' process, as carried on at the Newton Works and elsewhere, mentioning some of its advantages, but declining to place the material produced by the one process higher than that made by the other. He then exhibited a number of specimens of mild steel, including samples of Sir James Whitworth's compressed steel, as well as of Bessemer steel, and some excellent forged work in Siemens steel made by Messrs. Denny, cf Dumbarton. In reviewing the influence of the introduction of mild steel upon the iron industries, he paid special compliment to the Clyde shipbuilders for the way in which they had realized the advantages to be gained by the use of the new metal, and in which, through many difficulties, they had now come to reap in full success the reward. Not having for so long received their "fair share" (arithmetically speaking, of Government work, they had been free to form and carry out their own ideas of what was best in design and in material, unhampered by the views of any Government department, relying solely on the excellence of the work they turned out, the trustworthiness of their steamers, and the economy of their engines. Speaking of the use of mild steel in bridges, the lecturer said he was sorry that under existing circumstances it was not possible to give any definite information as to the material to be used in the Forth Bridge, when and in whatever form it was ultimately decided to erect it. He hoped, however, that when constructed, it would be one of the greatest examples, if not the greatest, of the use of mild steel in the world, and would very probably be an example of a structure whose very existence would scarcely have been possible but for this material. In closing, the lecturer remarked that before another generation we should, perhaps, see the last of the "puddling" process; and besides having a finer material, we should have the satisfaction of having abolished forever one of the last remaining processes in which man had been used just as a strong brute—a process which had hitherto held its own against any attempts to improve it. He was sanguine that before long ingot iron might be used not only instead of wrought, but also instead of cast iron in very many circumstances.—*Engineering.*

The Steel Trade of the World.—The total capacity of the steel mills at the present time throughout the world is estimated at about 3,000,000 tons for the year's production. In the United Kingdom there are 120 Bessemer converters built, of which over 80 are at work, and the annual yield from these is considered at from 755,000 to 800,000 tons. The American make is estimated at 750,000 tons, the next largest producer being Germany, which is considered by many to be capable of the greatest expansion among all the steel-making countries. Less than two years ago there were 25 converters in Prussia working out of the 50 built, and turning out 375,000 tons; which were increased by the works in Saxony and the Palatinate to 400,000; and since the revival in trade fresh converters have been put into operation. The estimate of the French steel manufacture is about 275,000 tons; that of Belgium, 150,000; of Austria, with 32 converters, 250,000; and of Sweden and Russia, 150,000. Of the Bessemer converters in England, the largest are two ten ton ones at Sir John Brown and Co.'s works at Sheffield, the others varing between three and eight tons in capacity; and out of the 24 British steel works 17 only have rail mills. Looking at the probable extension of railways for the next twelve months, it is difficult to see how all this large output of steel rails is to be utilized.

RAILWAY NOTES.

In offering prizes for the period of six years ending with July 15, 1881, the *German Railroad Union* suggests the following as especially desirable: (1) The invention of a locomotive, tender or car wheel of simple but safe design by which the loosening of tires will be effectively prevented. (2) The invention of a simple apparatus, which can be depended upon under all circumstances, which will render it possible for train men on different parts of a long train to communicate with the enginemen. (3) The invention of a cheap but reliable signal apparatus for the automatic blocking of trains which follow each other closely upon the open road, for regulating and rendering safe the traffic on crowded sections of road. (4) The invention of an apparatus which will make it possible for a train-man with the ordinary form of brake to apply the brakes simultaneously on two adjacent cars. This is required especially for freight cars. (5) Plans for improved statistics of the distribution and movement of cars, having regard to the administrative requirements of the separate roads, the settlement of the accounts for interchanged cars, and general statistical purposes. (6) The preparation of an exhaustive commentary on the working regulations, with special reference to the decisions of recent years. (7) A treatise based on statistical investigations on the influence and desirability of the present usual division of passengers and arrangement of cars into three or four classes, from a general public stand-point as well as with regard to the profit to the roads. (8) A short abridged encyclopædia of the technics of railroads, in the sense of genuine encyclopædia; that is, a systematic grouping of the materials and their relation to each. (9) A history of the development of freight tariffs and their influence on the public welware.—*Engineer.*

A Letter from Naples, written by one of the nine persons who made the experimental trip on the new railway to the crater of Vesuvius, gives some particulars of the line and the journey. The actual railroad is 800 meters long and terminates 200 meters short of the

mouth of the crater. The inclines are tremendous: Four in 10 for the first 135 meters; 63 in 100 for the next 330 meters; then 56, 52, and finally 48 in the 100, for the remainder. The carriages are drawn up by a steel rope of forty nine strands, which is coated with tar as a protection against rust. An hour's drive from Naples takes the traveler to the mountain observatory. An excellent new road, nearly two miles long, has been built by the railway company from the observatory to the railway station. The ascent on the railway was made in seven minutes, but it can easily be made in five. The motion was quite smooth, but the sensation on looking out is far from pleasant, and a feeling akin to seasickness is said to arise. The view from the summit repays all the trouble. The writer says that at every step one feels the proximity of the great storehouse of heat. He was informed that great pillars of smoke frequently burst up from the ground, close to the spot where the railroad ends, and great chasms open, swallowing up anything which may be on the spot, so that the expedition may sometimes not be wholly free from danger. It was intended to open the line for the public at the beginning of May.

ENGINEERING STRUCTURES.

The Tay Bridge Disaster.—After a protracted inquiry, extending over several weeks and involving twenty-six sittings, the Commissioners appointed to investigate the Tay Bridge disaster, with the view of determining its cause, have adjourned their meetings *sine die*. Those of our readers who have followed our weekly reports of the proceedings —condensed though they necessarily have been—or the more detailed statements in the daily papers, cannot fail to have observed that a vast amount of evidence was given, and that a large proportion of that evidence was of a very conflicting and contradictory nature. The contradictions, however, were largely confined to matters of opinion. Matters of fact could scarcely be liable to contradiction, and these to a great extent went to show the existence of defects in the parts of the structure. It may probably be some little time before the report of the Commissioners is made public, and until that time arrives it would be highly indecorous on our part to offer any critical observations on the evidence taken, or to indicate the conclusions to which it points. Indeed, this latter course would be somewhat difficult, owing to the conflicting nature of some of the statements, as already mentioned, and which may possibly necessitate further and personal local inquiry and investigation on the part of the Commissioners before their report can be completed. Originally commenced in Dundee and continued in London, the inquiry may possibly terminate in the former town. It may be taken for granted that the investigations of the Commissioners will be of the most searching character, their object being to render the repetition of such an accident as that of the 28th December last, as far as they can, impossible, by bringing to light its causes.

It is well known that the bridge, up to the time of its destruction, was generally looked upon as a pattern structure of its kind and one well worthy of imitation elsewhere as occasion might require. It is no less well known that not only structurally was the bridge thus viewed, but as a model of cheapness and rapid construction. As we briefly wrote on the 2nd of January last, so we now repeat, that it is impossible not to believe that those who had charge of the designing and constructing of the bridge did their best to ensure its safety. They doubtless took into consideration all the contingencies that were ever likely to affect its strength and stability; and it is in evidence that they prepared their designs accordingly, and in accordance with the best principles of modern engineering construction. The evidence of Mr. Benjamin Baker, a gentleman well qualified to offer an opinion, goes to prove this very strongly. He moreover stated that he considered the workmanship of the Tay Bridge, generally, was of good character. He observed, however, that good and bad work were relative and that he had seen both better and worse work than there was in that structure. But, however correct may have been the design, and however sound the general execution, there still remains the fact that the bridge was a marvel of cheapness and of rapid construction; and it may be a question how far these two conditions have affected and influenced the character of the more minute details of the work. At the same time and in the face of the defects which are stated to have existed in some of the castings, it is in evidence that those who were responsible appeared to have been fully alive to their responsibilities and to have acted accordingly.

Then again we have it stated that inferior Cleveland iron was used in some portions of the structure, against which we have the Commissioners stating that the court had received the results of some tests made by Mr. Kirkaldy as to the quality of the iron, and that the opinion of the court was that the iron was exceptionally good. It appears that the wrought iron in the bolts was of excellent quality, and only broke under a strain of 25 tons per square inch, whilst the tie-bars did not give way in the eyes until a strain of 20 tons per square inch had been reached. Portions of the girders bore respectively strains of 22½ and 23½ tons per square inch before breaking, and strips cut from the broken cast-iron columns bore a direct tensile strain of 9½ tons per square inch before yielding to stress. These figures speak for themselves and for the character of the metal. Mr. Law's evidence is certainly very damaging. He reported fully on the whole construction, which he condemns *in toto*, leaving an impression not of the most pleasant nature, and one, moreover, which it is to be hoped the report of the Commissioners will tend to modify. Then as to the Government inspection of the bridge, it is stated that that was far more carefully and closely performed than usual, and the tests showed the bridge to be far more stiff than had been anticipated. Thus, from first to last, the broad and general conditions of safety appear to have been duly re-

garded. It, however, remains to be seen to what extent subordinate supervision was carried, and whether sufficient attention was paid to the multifarious requirements of the structure in detail. There can be no doubt whatever that all these points will receive the fullest consideration at the hands of the Commissioners, and although the inquiry cannot recall the past, it can, and doubtless will, prove profitable in the future.

ORDNANCE AND NAVAL.

The fragments of the 38-ton gun destroyed for experimental purposes in the bursting-cell in the proof-grounds, Government Marshes, adjoining the Royal Arsenal, Woolwich, on Tuesday last, have all been recovered, and are found to number about 120 pieces. They have all been marked, and are being washed and arranged for inspection. The two projectiles were taken from the sand butt in front of the gun, both broken in pieces, and it is evident from the appearance of the bore that they broke up before leaving the gun, the marks of the rifling being in parts quite effaced. The muzzle end of the steel tube, about 3 feet in length, is intact, with parts of the wrought iron super-coil remaining attached, and a singular appearance is presented by the rearmost end of this fragment, the steel having been violently rent and incurved as though a shot or lighter fragment, moving faster than itself, had overtaken it and struck it with considerable force. The crusher gauges fixed on both projectiles have been recovered, but give no positive data respecting the pressure produced by the explosion. A very great pressure had been expected, and the copper crushers had consequently been subjected to a pressure of thirty-five tons to the square inch before being inserted in the plugs. This pressure was not exceeded in the explosion, and the only apparent deduction arrived at of importance is that a strain which would not be alarming in the powder chamber has sufficed to burst the gun at the spot where its thickness and strength suddenly diminished.

The Recoil of Ordnance.—One of the greatest difficulties attending the introduction of improved gunpowders and the consequent increase of power imparted to the guns has been the correspondent development of greater recoil. This has been a source of inconvenience in relation to all kinds of ordnance, but it has been increasingly felt in dealing with the lighter descriptions of guns, such, for instance, as those of the horse and field artillery and the siege train. With naval guns and garrison artillery the weight of the equipment, aided by breaks and hydraulic buffers, has to some extent met the difficulty, and improvements are now being tried at the Royal Arsenal, Woolwich, with contrivances by which it is hoped that at least a portion of the recoil may be absorbed even in the lightest of the gun carriages. A 64-pounder gun carriage is being experimentally fitted with hydraulic buffers, which will, undoubtedly, receive a portion of the shock on discharge, but as the recoil necessarily increases in ratio to the energy imparted to the projectile it is far from certain that the device will meet the growing demands of the artillerists.

A new explosive, denominated potentite, is finding favor for blasting purposes in the Cumberland and Furness mines.

BOOK NOTICES.

Publications Received.

We are indebted to Mr. James Forrest for the following publications of The Institution of Civil Engineers:

"Dredging Operations on the Danube." By Murray Jackson.

"The Thames Steam Ferry between Wapping and Rotherhithe." By Frederick Eliot Duckharn, M. I. C. E.

"The River Nile." By Benjamin Baker, M. I. C. E.

"New Zealand Lighthouses." By John Blockitt, M. I. C. E.

"Fire Hydrant." By Edward Henry Keating, M. I. C. E.

"A Rack-Railway Worked by Endless Ropes." By T. Aguido.

"Tunnel Outlets from Storage Reservoirs." By Charles John Wood, M. I. C. E.

"The Theory of Modern American Suspension Bridges." By Prof. Celeste Clericetti.

The Iron, Steel, and Allied Trades in 1879. Annual Report to the Members of the British Iron Trade Association. London: E. & F. N. Spon, and British Iron Trade Association. For sale by D. Van Nostrand.

The report before us comprises within its 111 pages a great variety of valuable statistics of especial interest at the present time to all concerned in the prosperity of our iron and steel industries, and it altogether reflects great credit upon Mr. Jeans, the secretary of the British Iron Trade Association (and also of the Iron and Steel Institute) who is responsible for its compilation.

The contents are divided into eleven chapters, of which the first deals with production and importation of iron ores.

Chapter II. deals with the pig iron trade, and contains copious information respecting the production of different districts, quantities of stocks, shipments, and prices of pig iron during series of years, together with notes concerning blast furnaces and the consumption of coal per ton of iron made. Chapter III. deals in a similar way with the manufactured iron trade, the information given being very varied.

The fourth chapter treats of the Bessemer steel trade, and from it we learn that at the end of 1879 there were 66 Bessemer converters in use in this country, while 38 were idle, and 11 in course of erection. The total quantity of steel ingots produced by the Bessemer process

in 1879 was 834,711 tons, while the quantity of steel rails turned out was 520,231 tons

The next chapter deals with British exports and imports of iron and steel, and from it we learn that the exports of 1879 showed an increase in quantity of 583,000 tons, and an increase of value of £1,045,000 as compared with the previous year, the quantity exported being in fact greater than during any year since 1873.

Chapter VII. treats of the coal trade in 1879, and shows amongst numerous other facts that the exports last year reached 16,535,642 tons as compared with 15,494,633 tons in 1878. Chapter VIII. treats of shipbuilding, and comprises some specially interesting statistics relating to the use of steel for this purpose, while next comes a chapter on railways and the iron trade, containing a variety of interesting information. "The Foreign Iron and Coal Trades in 1879" forms the subject of Chapter X., this chapter containing statistics which render possible some interesting comparisons between our own progress and that of other nations. Finally we have a chapter on "Tariff Legislation and the British Iron Trade," in which the tariff legislation of the last twenty years is reviewed, and information given as to the present aspect of the subject in Germany, France, Canada, and the United States. Altogether, as we have said, the report before us is a very creditable one to all concerned in its production, and we have no doubt that the information it affords will be widely appreciated.

Mathematical Drawing Instruments, and How to Use Them. By F. Edward Hulme, F. L. S. London: Trübner & Co. For sale by D. Van Nostrand. Price, $1.50.

This brief treatise is a convenience to the student, and invaluable to any one who is compelled to acquire a knowledge of draughting without a teacher. The illustrations are exceedingly good, and the instruction is throughout explicit.

Geology for Students and General Readers. By H. A. Greene, M. A.; F.G.S. London: Rivingtons. For sale by D. Van Nostrand. Price, $5.00

For a general book of reference relating to the technical points of descriptive and dynamical geology, nothing could be better, apparently, than this work. This remark seems necessary in view of the fact that geology for general reading is often held to imply essays like "Testimony of the Rocks," "Old Red Sandstone," etc.

The scope of the book before us may be inferred from the list of subjects:

Chapter 1. The Aim and Scope of Geology, with a sketch of its rise and progress.
Chapter 2. Descriptive Geology.
Chapter 3. Denudation.
Chapter 4. What becomes of the waste produced and carried off by denudation? The Method of Formation of Bedded Rocks, and some Structures impressed on them after their Formation.
Chapter 5. Definition and Classification of Derivative Rocks and how, from a study of their character, we can determine the physical geography of the earth at different periods of its past history.
Chapter 6. Volcanic Rocks.
Chapter 7. Metamorphic Rocks.
Chapter 8. Granite.
Chapter 9. How the Rocks came into the Positions in which we find them.
Chapter. 10. How the present surface of the Ground has been produced.
Chapter 11. Original Fluidity and Present Condition of the Interior of the Earth. Cause of Upheaval and Contortion. Origin of the Heat Required for Volcanic Energy and Metamorphism. Remarks on Speculative Geology.
Chapter 12. On Changes of Climate, and how they have been brought about.

The Art of Perfumery. By G. W. Septimus Piesse, Ph. D., F. C. S. Fourth Edition. Philadelphia: Presley Blakiston. For sale by D. Van Nostrand. Price, $5.50.

This work relates to a branch of industry which directly interests a large number of workers, and indirectly the public at large. It is essentially practical in its character, and is designed for dealers and manufacturers. It is beautifully illustrated, and includes an appendix on the artificial fruit essences for confectionary and syrups.

Turning and Mechanical Manipulation. Vol. IV. Principles and Practice of Hand or Simple Turning. By John Jacob Holzapffel. London: Holzapffel & Co. For sale by D. Van Nostrand. Price, $10.00.

This volume, which is of octavo size, is devoted exclusively to lathe work. Everything which the lathe is supposed capable of doing is discussed and illustrated in this book. The subjects treated by chapters are:

1. Introductory. Early History.
2. Center Lathes. Continuous Motion.
3. Lathes with Revolving Mandreis.
4. Modern Foot-Lathes.
5. Apparatus for Special Purposes.
6. Chucks and Apparatus for holding.
7. Practice of Soft-wood Turning.
8. Practice of Hard-wood and Ivory Turning.
9. Elementary Metal Turning.
10. Screw Cutting.
11. The Sphere, and forms derived from this solid.
12. Examples of Simple Plain Turning.
13. Examples of Combined Plain Turning.
14. Miscellanea. Staining, Dyeing, etc.

MISCELLANEOUS

A Deep Bore Hole.—The Continental Diamond Rock-Boring Company, Limited, have lately completed for the Government of Mecklenburg-Schwerin a bore-hole of exceptional depth, and the execution of which is of particular interest from the rapidity with which it has been completed. The boring, which was made for salt, is situated at Probst Jesar, near Lubtheen, and it was commenced on the 6th of July of last year, with an opening 12 inches in diameter. The first part of the bore had to be through a diluvial bed consisting mainly of drift sand and coarse gravel, and for sinking through this Kobrich's system was adopted, the diameter of the bore being maintained at 12 inches. The total depth sunk on this system was 98.05 meters, or 321 feet 8 inches, the sinking occupying 34 days of 24 hours each, of which 31 days were spent in actual boring and three days in sundry works. The average progress was thus at the rate of 3.163 meters per day, while the greatest depth bored in one day was 7.496 meters, this being on August 11, 1879.

Below the diluvium the gypsum and rock

were reached, and through this the boring was carried on with diamonds, the commencement being made on August 25, 1879, with a hole 10½ inches in diameter. Until a depth of 509 meters, or 1670 feet, had been reached, however, no firm footing could be obtained on which to rest the tubing, and hence great annoyance was experienced from the falling in of masses of sand, the infalls being so great that sometimes when the boring rod was withdrawn the bore became filled up again to a depth of over 420 feet. The boring, however, was steadily proceeded with, and ultimately the final depth of 1207.25 meters, or 3961 feet was attained on the 6th of February last, the diameter of the bore at the bottom being 3 inches. The time spent in boring with diamonds was thus 163 days of 24 working hours, and this time was accounted for as follows :

		days.
For progressive boring		70
" reaming up		8
" sundry works, *i. e* :		
Getting rid of infall	13	
Preparing and repairing tools	42	
Preparing lye	6	85
Letting down tubing	22	
Making good an accident	2	
Total		163

Altogether the depth reamed up amounted to 299.205 meters, the time occupied being divided as follows :

	meters.		in.		in.		days.
Enlarging	10.95	from	9	to	10½	in diameter.	0.5
"	87.555	"	8	"	9	"	3.0
"	98.000	"	7	"	8	"	1.0
"	39.700	"	3	"	5	"	0.5
"	63.000	"	3	"	4	"	3.0

The greatest progress made in any one day was on the 27th of January last, when a depth of 29 meters (95 feet 2 inches) was bored, this being nearly double the average progress. The total length of tube inserted was 1010.55 inches, or 3315½ feet, the greatest length inserted in one piece being 456.424 meters, or 1497½ feet and this consisting of 7 inch and 8 inch tubes. Throughout the whole depth of the bore cores were drawn, some of these being salt cores over 2 feet long in one piece.

With the exception of a bore-hole put down to the depth of 1275 meters, or 4183 feet, for the Prussian Government a few years ago, and which took four years to accomplish, the bore of which we have been giving particulars is, we believe, the deepest yet sunk, and the fact that it was completed in less than six months speaks well for the skill and energy with which the work was carried out.

M. Colladon has read a paper "On the Meeting of the Two Advance Galleries of the Great St. Gothard Tunnel," which gives various interesting details, including the volume of infiltrations in the south gallery which reached 230 liters per second. The difference of level at meeting was not over 0.10m.; the lateral deviation less than 0.20m. The total length measured in the tunnel was nearly 8m. less than that calculated geometrically. The official statement made by the Swiss Federal Council shows that the cost of the St. Gothard Tunnel from the commencement up to March 1st., the total amount expended on the work was 45,600,000f., or £1,824,000 sterling. The work on the Airolo side cost rather less than on the Göschenen side, the amounts expended being 21,800,000f. and 23,200,000f. respectively. The difference about corresponds with the different lengths done on the two sides, the portion from the Göschenen end being rather more than half. The finishing operations will take some little time, and it is estimated that by the time the tunnel is ready to be handed over for traffic it will have cost altogether about 50,000,000f., or £2,000,000 sterling. This will bring the cost up to about 1000f., or £40 per foot.

According to the last report of the Indo-European Telegraph Department, the distance between London and Teheran is about 3,800 miles; the average time of transit of all messages is given as 17 min. 30 sec.; while the time occupied in transmitting messages between Teheran and Bushire is stated at 2 min. 58 sec.

Two German inventors, Breuer and Schumacher, have made a new form of machine for separating the turnings and borings of brass and copper from those of iron and steel. The mixed metals fall on a magnetised cylinder or drum, to which the iron and steel adhere, while the copper and brass fall into a special reservoir below. There are two hollow cylinders rotating in the same direction, so that the iron which escapes from the first cylinder is retained by the second. The surface of the cylinder is formed by flat bands or strips of soft iron alternating with strips of copper, and each of the iron bands is in contact with a row of horseshoe magnets. The adherent metal is removed by revolving brushes.

At the foot of Mt. Vesuvius there is now the new station of the railway to the summit of the old crater. It is on a level spot on the west side of the mountain, about half-an-hour's walk from the Observatory. As before, the traveler must reach the Observitory from Resina by carriage or on horseback. There are two lines of rails, each provided with a carriage divided into two compartments and capable of holding six persons. While one carriage goes up the other comes down, the two hanging from the end of a wire rope running over a pulley at the summit. The incline is very steep, commencing at 40 deg., increasing to 63 deg. and continuing at 50 deg. to the summit. The ascent will be made in eight to ten minutes, which before required from one to two hours. To obtain the necessary supply of water, large covered cisterns have been constructed, which in winter will be filled with the snow that often falls heavily on Vesuvius. On reaching the top there is still the new and smaller cone to be ascended by those who are charmed by risk and adventure.

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THE FRENCH ROOF TRUSS.

By P. H. PHILBRICK, Prof. of Civil Engineering, State University, Iowa.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE French Roof Truss is one of the most popular forms in use. Its economic proportions and its beauty are both in its favor, and conspire to give it a place among the leading forms of roof trusses. The roofs of some of our most spacious and elegant railway station buildings are supported by this truss. Over our machine shops, foundries and industrial works of all kinds, it may be seen; and it quite as frequently spans the walls of the college or the public hall.

The analysis of this truss becomes, therefore, of special importance, though it has been generally, at least partially, neglected, or erroneously treated, by writers on bridges and roofs. Some have given results wide of the truth, others results more nearly correct. Some have given a partial analysis only, others none at all. On one point many agree: that the case is a simple one, and can be safely left to the student himself. In a treatise, perhaps in the hands of more architects than any other, the treatment of this truss is erroneous in several respects and in a marked degree. A brief description of the truss will suffice.

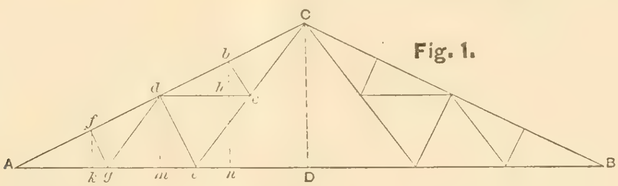


Fig. 1.

AB is the long tie and AC and BC the main rafters. AC is supported at d by the inverted king-post AeC, in which the post de is perpendicular to AC, and extends to AB. Ae and Ce are the tie rods. The tertiary trusses Agd and deC are added. The arrangement of the parts and pieces is apparent from the figure.

NOTATION.

Let W = total load on the roof.

N = number of panels in both rafters.

$\frac{W}{N} = p$ = load at each of the joints b, d, f, etc.

V = reaction at A $= \frac{1}{2}W = \frac{1}{2}Np = 4p$.

AD $= s$, AC $= l$ and CD $= d$.

t_1, t_2 and t_3 = tension on De, eg and gA respectively.

c_1, c_2, c_3 and c_4 = compression on Cb, bd, df and fA respectively.

ANALYSIS.

I. The load at b is sustained directly by bc and bd, and we have:

Strain on

$$bc = p\frac{AD}{AC} = p\frac{s}{l} \quad . \quad . \quad . \quad . \quad (1)$$

$$bd = p\frac{CD}{AC} = p\frac{d}{l} \quad . \quad . \quad . \quad . \quad (2)$$

and the same equations apply to fg and fA.

Furthermore, the strain on $bc\left(=p\frac{s}{l}\right)$ causes strain on Cb, bd, Cc and cd, which strains, according to the principles of the king-post truss are:

Strain on

$$Cb \text{ or } bd = \tfrac{1}{2}p\frac{AD}{AC}\times\frac{Cb}{cb} = \tfrac{1}{2}p\frac{\overline{AD}^2}{CD.AC}$$

$$= \tfrac{1}{2}p\frac{s^2}{dl} \quad . \quad . \quad . \quad (3).$$

And the same on df or fA from the strain on fg.

Strain on

$$Cc \text{ or } cd = \tfrac{1}{2}p\frac{AD}{AC}\times\frac{Cc}{bc} = \tfrac{1}{2}p\frac{AD}{AC}\times\frac{AC}{CD}$$

$$= \tfrac{1}{2}p\frac{s}{d} \quad . \quad . \quad . \quad (4).$$

And the same on dg or gA from the strain on fg.

Again the strut de sustains one half the pressures or loads at b and f, and $p\frac{AD}{AC}$ directly from the load at d.

Hence, strain on

$$de = 2p\frac{AD}{AC} = 2p\frac{s}{l} \quad . \quad . \quad . \quad (5).$$

This pressure on de gives, according to equations (3) and (4):

Strain on

$$Cd \text{ or } dA = p\frac{AD}{AC}\times\frac{Cd}{ed} = p\frac{AD}{AC}\times\frac{AD}{CD}$$

$$= p\frac{s^2}{dl} \quad . \quad . \quad . \quad (6)$$

$$Ae \text{ or } eC = p\frac{AD}{AC}\times\frac{Ce}{de} = p\frac{AD}{AC}\times\frac{AC}{CD}$$

$$= p\frac{s}{d} \quad . \quad . \quad . \quad (7).$$

TOTAL STRAINS.

From (1) strain on bc or $fg = p\frac{s}{l}$ . . . (1)

" (5) " " de $= 2p\frac{s}{l}$ . . . (5)

" (4) " " cd or dg $= \frac{1}{2}p\frac{s}{d}$ . . . (4)

From (7) strain on ec $= p\frac{s}{d}$ . . (7)

" (4) and (7) " " cC $= \frac{3}{2}p\frac{s}{d}$. (8)

To find tension t_1 on De, consider AB severed at D and take moments about C. We have:

$$t_1 d = Vs - V\times\tfrac{1}{2}s = \tfrac{1}{2}Vs = 2ps. \therefore t_1 = 2p\frac{s}{d} \quad . \quad . \quad (9)$$

Now (7) + (9) gives strain on

$$eg = t_2 = 3p\frac{s}{d} \quad . \quad . \quad . \quad . \quad (10)$$

Also (4) + (10) gives strain on

$$gA = \frac{7}{2}p\frac{s}{d} \quad . \quad . \quad . \quad . \quad (11)$$

Strain on Af = strain on

$$gA\frac{l}{s} = \frac{7}{2}p\frac{l}{d} \quad . \quad . \quad . \quad (12)$$

And observing that the strain on any section of the rafter exceeds the strain on the adjacent section above by $p\frac{d}{l}$ given by (2) we have:

Strain on $fd = \quad \frac{7}{2}p\frac{l}{d} - p\frac{d}{l}$ . . . (13)

" " $db = \quad \frac{7}{2}p\frac{l}{d} - 2p\frac{d}{l}$ . . . (14)

" " $bC = \quad \frac{7}{2}p\frac{l}{d} - 3p\frac{d}{l}$ . . . (15)

II. We may first find the strain on the upper section of the rafter, then on the other sections by addition, and on the other members of the truss as before.

From the truss Ccd strain on

$$Cb = \tfrac{1}{2}p\frac{s^2}{dl} \quad . \quad . \quad . \quad . \quad (16)$$

From the truss CeA strain on

$$Cb = p\frac{s^2}{dl} \quad . \quad . \quad . \quad . \quad (17)$$

The $\frac{1}{2}p$ at C gives by equation (2) a strain on

$$Cb = \tfrac{1}{2}\frac{d}{l} \quad . \quad . \quad . \quad . \quad (18)$$

And besides these, there will be compression also on Cb due to the thrust at C, the same as though the rafters were not trusses.

Let H in Fig. 2 = the horizontal thrust at C, and L the component of that thrust in the direction of CA. Then:

$$\mathrm{H}\times\mathrm{CD}=\tfrac{1}{2}\mathrm{W}\times\tfrac{1}{2}\mathrm{AD}=\tfrac{1}{4}\mathrm{W}\times\mathrm{AD}$$

$$\therefore\ \mathrm{H}=\tfrac{1}{4}\mathrm{W}\frac{\mathrm{AD}}{\mathrm{CD}}=2p\frac{s}{d}.$$

$$\mathrm{L}=2p\,\frac{s}{d}\times\frac{s}{l}=2p\frac{s^2}{dl}\dots(19)$$

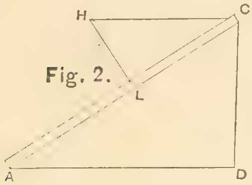


Fig. 2.

Now adding (16), (17), (18) and (19) we have compression on

$$\mathrm{C}b=\tfrac{1}{2}p\frac{d}{l}+\tfrac{7}{2}p\frac{s^2}{dl}$$

$$=\tfrac{1}{2}p\frac{d}{l}+\tfrac{7}{2}p\left(\frac{l}{d}-\frac{d}{l}\right)$$

$$=\tfrac{7}{2}p\frac{l}{d}-3p\frac{d}{l}\quad\cdot\quad\cdot\quad\cdot\quad(15)'$$

which is the same as (15).

III. The case is readily solved by moments. To find strain on De consider De severed and take moments about C; and similarly for eg taking moments about d, and for gA about f. Hence:

$$t_1=\frac{\tfrac{7}{2}ps-p\times\tfrac{3}{4}s-p\times\tfrac{1}{2}s-p\times\tfrac{1}{4}s}{d}$$

$$=2p\frac{s}{d}\quad\cdot\quad\cdot\quad\cdot\quad(9)$$

$$t_2=\frac{\tfrac{7}{2}p\times\tfrac{1}{2}s-p\times\tfrac{1}{4}s}{\tfrac{1}{2}d}\qquad=3p\frac{s}{d}\quad\cdot\quad\cdot\quad\cdot\quad(10)$$

$$t_3=\frac{\tfrac{7}{2}p\times\tfrac{1}{4}s}{\tfrac{1}{4}d}\qquad=\tfrac{7}{2}p\frac{s}{d}\quad\cdot\quad\cdot\quad\cdot\quad(11)$$

To find strain on $cd(=dg)$ consider dg severed and take moments about b. We have:

Strain on $cd\times bh=\tfrac{1}{2}p(\text{at }d)\times dh$

$$\therefore\ \text{Strain on } cd \text{ or } dg=\tfrac{1}{2}p\frac{dh}{bh}=\tfrac{1}{2}p\frac{s}{d}\ .\ .\ .\ (4)$$

Strain on ec = strain on eg − strain on De

$$=3p\frac{s}{d}-2p\frac{s}{d}=p\frac{s}{d}\quad\cdot\quad\cdot\quad\cdot\quad(7)$$

Strain on cC = (4) + (7)

$$=\tfrac{3}{2}p\frac{s}{d}\quad\cdot\quad\cdot\quad\cdot\quad(8)$$

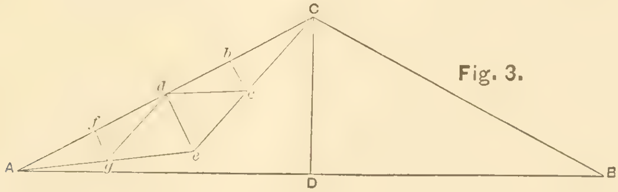


Fig. 3.

To find strain on Af or fd take moment about g. Hence:

$$c_1=\tfrac{7}{2}p\frac{\mathrm{A}g}{\mathrm{A}f}=\qquad\tfrac{7}{2}p\frac{l}{d}\quad\cdot\qquad\cdot\quad(12)$$

$$c_3=\tfrac{7}{2}p\,\frac{\mathrm{A}g-pkg}{fg}=\tfrac{7}{2}p\frac{l}{d}-p\frac{d}{l}\quad\cdot\qquad\cdot\quad(13)$$

To find strain on db and cd severed and take moments about e. Hence:

$$c_2\times de-\tfrac{1}{2}p\frac{s}{d}\times\tfrac{1}{2}d=\tfrac{7}{2}p\times\mathrm{A}e-p\times ke$$
$$-p\times me.\ .\ .\ .\ (\textit{See } 4).$$

or

$$c_2\times de-\tfrac{1}{4}ps=\tfrac{7}{2}p\times\mathrm{A}e$$
$$-2p\times me-p\times km=$$
$$\tfrac{7}{2}p\times\mathrm{A}e--2p\times me-\tfrac{1}{4}ps$$

$$\therefore\ c_2=\tfrac{7}{2}p\frac{\mathrm{A}e}{\mathrm{D}e}-2p\frac{me}{de}=\tfrac{7}{2}p\frac{l}{d}-2p\frac{d}{l}=\dots(14)$$

and similarly for the strain on bC.

Or strain on bc = strain on bd − (strain on fd − strain on bd)

$$=\tfrac{7}{2}p\frac{l}{d}-3p\frac{d}{l}\quad\cdot\quad\cdot\quad\cdot\quad(15)''$$

the same as (15).

The parallelogram of forces, the general equations of mechanics, or any other means of effecting the solution would yield the same results which we must conclude are correct.

In case the strut de does not extend to the tie-rod AB, the strains will be somewhat modified. On the struts and long tie the strains will be the same as in the preceding case. On the tie rods they will be greater because the trusses Agd, AeC, etc., are lower. The same equations, however, apply.

Thus the strain on Cb or bd, through

bc. and on dt or fA, through fg, is given by equation (3) and

$$=\tfrac{1}{2}p\frac{AD}{AC}\times\frac{Cb}{bc} \quad . \quad . \quad . \quad (3)'$$

which is greater than in the preceding case since bc is smaller. Similarily the strain on Cc or cd, through bc, and on dg or gA, through fg, is given by equation (4) and

$$=\tfrac{1}{2}p\frac{AD}{AC}\times\frac{cC}{cb} \quad . \quad . \quad . \quad (4)'.$$

This is the total strain on cd or dg.

Strain on Cd or dA, through de, is given by equation (6) and

$$=p\frac{AD}{AC}\times\frac{Cd}{ed} \quad . \quad . \quad . \quad (6)'$$

And the (total) strain on ce or eg, hrough de, is by equation (7):

$$p\frac{AD}{AC}\times\frac{Cc}{de}=p\frac{AD}{AC}\times\frac{cC}{cb} \quad . \quad . \quad . \quad (7)'$$

Total strain on cC or gA$=(4)+(7)'$

$$=\tfrac{3}{2}p\frac{AD}{AC}\times\frac{cC}{cb} \quad . \quad . \quad . \quad (8)'$$

The strain on Cb due to the load at C, as well as that due to the thrust at C, is the same as in the preceding case; and the strain due to the small trusses is given by equations (3)′ and (6)′. Hence adding (3), (6), (18) and (19) we have:

Strain on

$$Cb=\tfrac{3}{2}p\frac{s}{l}\times\frac{bC}{bc}+\tfrac{1}{2}p\frac{d}{l}+2p\frac{s^2}{dl} \quad . \quad . \quad . \quad (15)'$$

The strain on bd exceeds this by $p\frac{d}{l}$ and on df by $2p\frac{d}{l}$, and on fA by $3p\frac{d}{l}$.

EXPLOSIONS AND EXPLOSIVES.

From "The Builder."

As the shadows of evening close over a modern city, a sense of quiet, to some extent, replaces the busy activity of the day. Those inhabitants who, from daybreak or from, at least, an early hour in the morning, have been actively engaged in the pursuit of their daily occupations, gather round the domestic hearth, share the evening meal, and prepare for the well-earned repose of the night. The student hails the comparative quiet, and renews his study. Among the more wealthy and leisurely classes the attraction of the dinner-table, of the drawing-room, or of the theaters, commences, and the life of pleasure finds its noon. Rest, amusement, and calm study divide the time.

If, at this period of the day, a sudden blow, like that of hammer wielded by a giant, strike the house,—a blow followed by the immediate extinction of gaslights, and the tinkling sound of falling and shivering glass, to the effect on the nerves is one not easily forgotten. Having experienced that effect more than once or twice, and that from very different causes, we can form some conception of the effect produced on the inmates of the Winter Palace at St. Petersburg, by the explosion of a charge of dynamite in the guard-room shortly after nightfall on the 17th of February.

There are four sources from which sudden explosive shocks occur; and it so happens that we have had some close experience of three out of the four. Of the effect of a bombardment, the most alarming of all, from its persistency we cannot speak with this experience, having only heard the sullen thunders of such an attack from a safe distance on the spurs of the Apennines. But with explosions of gunpowder, sudden outburst of volcanic energy, and earthquake, we have direct acquaintance. Of these the most terrific is the earthquake; as the utterly illimitable power that is behind even the feeblest shock impresses the imagination, or, at all events, the emotional feeling, with a very solemn terror. But the most startling are the explosions into which human agency enters, whether it be that of gunpowder and kindred matter, of gas, or of steam.

In the case of the explosion, within the precincts of a populous town, of a large quantity of gunpowder or of any similar substance, an additional terror is caused if it occur by night. There is

not only that sense of unpreparedness for any sudden call on the energies to which we before alluded, but there is the added terror of sudden darkness. The instant extinction of gas is a usual consequence of an explosion of a certain force. Other lights, as far as our experience goes, are unaffected, unless incidentally, by such a shock. But over a large area of ground every gas-lamp in the streets, and within certain limits all those in the houses, are immediately put out. The reason no doubt is that there is a sudden pressure exerted by the atmosphere, which drives back the gas into the pipes; and the momentary cessation of the flow, of course, puts out the light. It must be remembered that a pressure equal to that of a column of about half an inch of water is all that can be placed on issuing gas without great loss of light. This pressure is very much less than that suddenly impressed on the atmosphere, and communicated to a very great distance from the center of explo sion, by the sudden development of a large volume of explosive gas. Here is, therefore, a danger apparently inseparable from the use of gas as a source of illumination in any locality subject to explosions.

A second danger, of course, follows from the extinction of gas. Every jet continues to pour forth its stream of unconsumed combustible vapor. Happily, in this case, the foul smell, which is one of the disadvantages of gas, is in itself warning of the pressure of the dangerous element, and serves to lead the careful housekeeper to the source of danger. But in a large building, such as a theater, unless there be in command some one of sufficient presence of mind at once to cut of the main supply, an explosive mixture would very soon be formed, and the consequences would be not only alarming, but disastrous. In one of the explosions above referred to, that of the *Carlo Terzo* frigate, in the harbor of Naples, in the winter of 1856–7, the great theater of San Carlo was full of its usual Sunday company at the moment of the explosion, which was about 11:30 p. m. The gas-lights in the theater, as well as those in the streets and houses, were at once extinguished by the explosion. It is to be presumed hat some one had the presence of mind to attend to the main. The building is one of the largest theaters in Europe, and the heat, when the house is full, is intense, especially in the upper galleries. The first thought of every one was how to get out. But for the fact that wax torches are burned as well as gas on the more important occasions in this theater, the terror which was actually felt might have been attended by a worse catastrophe.

There is thus in all houses where gas is consumed the added danger of subsidiary explosions that ensues on any great shock, such as those of which we have just spoken. But the sudden darkness that follows the blow is not all that adds terror to the scene. The same action that extinguishes the gas forces the glass of the windows from their frames. The fragile material is not strong enough to resist the sudden pressure over its whole surface. We are not aware that any calculations have been made either of the resisting power of glass to pneumatic pressure, suddenly applied, or of the pressure developed over a given area by the explosion of a given weight of powder. But we can speak from actual experience as to the effect. Our readers may remember the damage done to windows, and even to doors, by the explosion on the Regent's Park Canal, not so very long ago. On two occasions at Naples, that of the explosion of the powder magazine at the Port, and that of the *Carlo Terzo* (which occurred within a few weeks of one another), the destruction of glass within a radius of 1,000 or 1,500 yards was total. Not a window was left looking on the street for a considerable distance from the centers of explosion. It might have, perhaps, been anticipated that the windows would have been blown inwards. But, in point of fact, the panes of glass fell out on the balconies or on the pavement, which was immediately covered, for miles in extent if all the streets were measured, by a fine white shining gravel, consisting of pulverized glass.

To the terror of darkness and of the sound of breaking glass will be added a thousand other elements of terror which do not come within the province of the builder or the engineer to describe.

With a great mass of people the idea that the end of the world has come will

be found to be prevalent. This kind of terror is probably more common in countries where earthquakes and volcanoes are unknown, as the occasional sudden outburst of these great natural energies gives a sort of education to those who are exposed to them,—an education as to the possible occurrence of unexpected shocks, of which the inhabitants of districts not subject to these great meteoric disturbances are—perhaps we ought to say happily—destitute. Then comes the terror of evil men. Revolution is the first thought, often incorrectly feared. But the readiness with which those classes which prey upon their more wealthy fellow citizens will be likely to avail themselves of the facilities afforded by sudden darkness, and the partial destruction of the usual defences of the dwelling-house, is likely to depend chiefly on the fear with which they are themselves impressed. If there was any ground known to these people for anticipating an explosion, they would probably have prepared themselves for taking full advantage of the terror which it would be likely to spread.

These remarks have been suggested by the accounts that have excited so painful an interest in this country of alarming recent explosions. The attention of men of science, and, to a certain extent of the public, has been directed to the subject of explosive mixtures of late, partly by the great progress made in the improvement of artillery, and partly by the kindred advance made in the construction of torpedoes. We are as yet without a unit of explosive power. We can compare one substance with another, and we can compare one weapon with another. But it is only by this sort of rule-of-thumb measurement that we can as yet in any way predict the effect of an untried mixture, or an untried method of applying it. A range of eight miles has been attained by a projectile, and by enlarging the chambers and elongating the muzzle of our guns, the muzzle velocity attained is continually on the increase. The torpedo is, virtually, a movable mine, and torpedoes have been used in American waters containing as much as a thousand pounds of gunpowder. A regular torpedo service was organized during the war.

There is one consideration, we can hardly say of comfort, but yet to a certain extent pointing in that direction, attaching to the recent atrocious attempts at destruction in Russia. That is, that no artillerist, engineer officer, or man practically familiar with the legitimate use of explosive substances, has had any visible hand in them. It will be obvious why we employ a certain reserve in referring to this point. We cannot allow our pages, however indirectly, to give any hints that might be used for a mischievous purpose. But this we may safely say, the effect of the explosive force has been in each instance wholly inadequate to the cost and risk (to speak of nothing else) incurred in making the preparations for the explosion. This has been due, not so much, we think, to the employment of an insufficient quantity of dynamite or other explosive material, as to an ignorance of the rules which, happily for society, control the action of all explosive force. At the same time, there can be no doubt that the estimate of the quantity of dynamite exploded in the Winter Palace is a gross exaggeration; 126 lbs. of this substance, which is the quantity mentioned in the telegrams, would be equal in explosive force to more than thirteen barrels of powder, an allowance sufficient for blowing up, not a room only, but a magazine. It is probable that some error was made by the reporter, for it was added General Todleben said that if 10 lbs. more of the explosive material had been used, the effect would have been wholly ruinous. The addition of the latter quantity to the former would have only added 16 per cent. to the explosive power (the respective forces being as 15,876 to 18,496;) and no engineer would pretend to speak with certitude within so small a limit, unless he knew the exact facts, which have, in this case, of course been veiled by the explosion.

Those of our readers who are artillerists will fully understand our reference, and will agree with the only rational deduction. Those who are not, will be better content to take our opinion as it is offered, than to ask for that further information of which mischievous use might be made. But it is interesting to trace the difference between the results of the information which can be obtained

from books, and that which is learned in a practical apprenticeship. No doubt the difference is on the decline, but yet we may anticipate that it will never wholly disappear. We see that the executors of these mischievous projects have made themselves acquainted with the progress of scientific discovery. They have learned what explosives are the most compact and manageable. They have acquainted themselves with the infernal ingenuity of the "Thomas clockwork machines." They have learned how to arrange the wires, and how to work the electric battery. Here they stop; and it is some comfort for society to see that the amateur destroyer betrays the want of practical training. None the less do we feel convinced that the magnitude of the charges has been overstated. We doubt if the explosion, even in the open air and in an open space, of anything like 120 lbs. of dynamite would leave a pane of glass in a window within half a mile, or a larger radius. By the explosion of a few cans of nitro-glycerine on the wharf of Aspinwall, in 1866, a considerable portion of the town was destroyed, shipping at some distance in the harbor was much damaged, and a number of lives were lost. An explosion of a storehouse containing some hundreds of pounds of nitro-glycerine took place at Fairport, Ohio, in 1870, accompanied by much loss of life. The shock was felt at Buffalo, 160 miles distant.

Dynamite is a substance which was invented in 1867 by Nobel, with the idea of producing an explosive for mining purposes which should be less dangerous to handle than nitro-glycerine. It consists of three parts nitro-glycerine and one part infusorial silica, or porous earth. The presence of the silica renders the powder less liable to explode from concussion. The above is the true dynamite, but the word is used as a generic name for other mixtures of nitro-glycerine, such as colonia powder, which is gunpowder, with a mixture of 40 per cent. of nitro-glycerine; dualine, which contains from 30 to 40 per cent. of nitro-glycerine mixed with sawdust saturated with nitrate of potassia; and litho-fracteur, which contains 35 per cent. of nitro-glycerine mixed with silica, and a gunpowder made with nitrate of baryta and coal.

The explosive energy of nitro-glycerine is given at from four to thirteen times that of rifle-powder,—a wide margin. M. Berthelot gives, in the "Annales de Chimie et de Physique," a table showing the relative force of explosives. Of these, gun-cotton mixed with chlorate is the most formidable, next to nitro-glycerine, which is calculated at 6.78 times the force of powder used by the sportsman. This powder is somewhat stronger than that used for cannon, and is as 1 to 633 compared with that used for mines. That not only competent experience, but calm courage, is necessary for any certainty in dealing with these terribly dangerous materials, there can be no doubt. It may well be questioned whether perfect freedom in the manufacture, sale, and transport of such substances is consistent with national safety. It is not difficult to manufacture nitro-glycerine; but those who attempt to do so with anything of the secrecy of the smuggler are dealing with danger. Their lives are in their hands; and not only so, but the danger to their neighbors is very great. Society should demand that every guarantee for safety should be given by any persons who are engaged in these delicate and dangerous operations. Even with all the precautions that are taken in the manufacture of gunpowder, either by the Government or by well-known and respectable manufacturers, scarcely a year passes without a fatal explosion. If such be the risk attending the manufacture of a substance so comparatively inert as gunpowder, which is not liable to ignite by concussion or by pressure, what must be that attendant on every stage of the production, stowing, transport, and use of a composition of the terribly unstable nature of any nitro-glycerine explosive?

In speaking of the evidence of the absence of an educated artillerist or engineer on the two occasions of the explosion under the Moscow Railway, and that at the Winter Palace at St. Petersburg, we must not be understood as in any way underrating the terrible gravity of the situation. It is not in these columns that we have any political opinions to express. But the existence of society is a matter above all politics. The safety of the fireside is only to be endangered by those who deserve the title of

enemies of the human race. Even as we write the electric wires bring intelligence of the discovery of an infernal machine at Constantinople. Dynamite and bombs have been, it is said, found, which it is supposed were intended to be used against the Sultan. And we must remember that the more rude and inexperienced the hands into which such terrible agencies are put, the greater the danger to the public at large. The use of petroleum at Paris, under the frantic reign of the Commune, was to a great extent committed to women. The term "*pétroleuse*" thus passed into the French language. If there is any form of human crime and madness which more revolts the instinct of the architect, or of all those who are interested in the grandeur and stability of our public monuments, or the tranquility and security of the domestic abode, it is this new outbreak of destructive frenzy. Not only has there been an unsparing use of means of destruction, in which human life has been struck at, and the cost of any material mischief has been disregarded, but there has been the direct attempt to produce terror by attacking palaces, houses, and public buildings. Fire is called in to complete the ravages of gunpowder. The number of fires that have of late been reported as occurring in Russia is such as to point to the great improbability of their being the work of accident or of carelessness. That for the last few weeks we have heard little of such conflagrations by no means shows that they have ceased.

It is true that these outbursts of human malevolence are as nothing when compared to the overwhelming might of the earthquake. Within a few months of the time when Naples was shaken by the two explosions above referred to, the city was also subjected to a night of earthquake, in which, after the first sudden and terrible shock, as many as thirty-six smaller shocks succeeded. Hardly an individual in Naples passed that night in bed. The squares and public places were filled, the churches were besieged by throngs of terrified suppliants. But the damage actually done in the city was small. Campania was only on the fringe of the earthquake. In Basilicata the number of churches and houses thrown down was very large, and 30,000 people are said to have perished on that night in that province.

The great contrast that exists between the narrow range of the directly destructive energy of explosives, and the wide area shaken by an earthquake may be referred to as a comparative mitigation of the terror inspired by the human mechanism. It is a relief to the mind to turn for a few moments to the contemplation of the use of the torpedo for the direct service of mankind. In the petroleum regions of the United States nitro-glycerine has been introduced into some of the exhausted oil-wells, and exploded at great depths beneath the surface, with the intent of opening fissures that should tap fresh supplies of oil. Cartridges of 25 in. and 35 in. long and 5 in. diameter were prepared, and lowered into the bore-holes until they were opposite the mud-veins known to exist at certain levels. They were then exploded by electricity, arranged to run through copper wires. The method has been protected by patent, and is said to have restored productiveness to many exhausted wells.

A smile may be excited at an application of cartridges of "gravel powder" to what the Americans politely call trout-fishing in the Rocky Mountains, but which we most brand as unmitigated poaching. Of course it is one thing to try to kill fish for food, where food is only to be obtained by the chase, and another to enjoy the sport of the angler. A cartridge of gravel powder, containing about a quarter of a pound, is dropped into any deep hole in the river supposed to be haunted by fish, and exploded by a fuse. It kills or stuns all the fish within a radius of 30 feet or 40 feet, and they are captured as they float to the surface. We commend this sub-aquatic infernal machine to the condemnation of all true sportsmen; even as we denounce the resort to the murderous force of explosives whenever they are employed without the most distinct ground of justification.

THE BEST ROUTE FOR A LINE OF RAILWAY TO INDIA.

By B. HAUGHTON, C. E.

From the "Journal of the Society of Arts."

The first sod of that railway has been already cut which is the subject of this paper, and which I have ventured to call "a line of railway to India." The act has taken place at the Indian terminus, at Shikarpore, on the Indus, the point of its junction with the Indus Valley Railway. The line owes its inception to the war now being waged in Afghanistan, and to the pressing necessity for pushing our troops and their *impedimenta* into the enemy's country. It is called in India "the Candahar Railway," and it is said that, in January last, it had reached its 139th mile, near the south end of the Bolan Pass. The city of Candahar is 350 miles, and Herat is 650 miles, from the terminus. It is almost certain that Candahar will be reached before the close of the current year, and without doubt no time will be lost in the extension to Herat "the key of India."

The subject of a railway to India has been discussed over and over by some of the most active, thoughtful, and enlightened men of the age. I cannot, therefore, hope to do much more than bring forward an old subject, dressing it in somewhat of a new garb, at a period when it has certainly obtained new attractions and a new value, owing to political changes that have occurred; to the additional light that has been thrown on it as the years roll on; and owing to the circumstances that it is an essentially progressive subject.

In preparing this paper, I have to express my indebtedness to those great masters of the question who have lived, and worked, and traveled, in the parts concerned, some of whom have written much upon it—viz., General Chesney, Sir Henry Rawlinson, Mr. William Patrick Andrew, Mr. T. R. Lynch, Sir Bartle Frere, Sir Rutherford Alcock, Lord Stratford de Redcliffe, Lord Sandhurst, Lord Strathnairn, General Sir Arnold Kemball, Rev. James Long, Von Hochstetter, the President of the Geographical Society of Vienna, Sir John Mac Neill, C. E., Mr. Ainsworth, Captain Jones, Captain Charlewood, and others, several of whom have so thoroughly illuminated the subject by their evidence, given before the Select Committee of the House of Commons, in 1871-2, a committee which sat under the distinguished chairmanship of the present Chancellor of the Exchequer.

For myself, I may say that my interest in the question arose on that memorable 13th of October, 1869, when, thanks to the hospitality of his Highness the Khedive of Egypt, I stood on the forecastle of one of his despatch boats, the *Fayoum*, and watched the procession of the ships as they filed past into the "maritime canal of Suez," and on board of which many of the nations of Europe were represented by their emperors and princes, headed by the Empress of the French, in her yacht *L'Aigle*, followed by the Emperor of Austria, and the King of Prussia. England, conspicuous by the absence of any royal deputy, was unofficially visible in the person of the Admiral of the Mediterranean fleet, who steamed through the Canal gaily in his yacht, the *Deerhound*. Lord Houghton and Lord Alfred Paget, Sir John Hawkshaw, C. E., and Mr. Bateman, C. E., Mr. Gregory, M. P., Mr. Pender, M. P., Mr. Ramsay, M. P., were there. Liverpool was represented by Mr. Charles Clarke, president of the Chamber of Commerce; Manchester, by Mr. Grave, Mayor, and Sir John Bennett, chairman of the Cotton Supply Association. Glasgow, Edinburgh, Birmingham, Sheffield, and Bristol also were represented; Mr. W. H. Russell and many members of the Press were there; while four British ironclads added a certain picturesque effect to the scene, as they lay at anchor in the offing.

The witnessing of such a remarkable assemblage and brilliant pageant, having for its stage Egypt and the newly excavated maritime Canal of Suez, was sufficient to leave an ineradicable impression

on the mind as to the importance of the occasion, and the magnitude of the issues bound up in the existence of this famous waterway; and that importance has not been diminished after ten years' experience of its working, and the near one million of pounds sterling of gross revenue that it now returns per annum to its proprietors.

The common conversation, then, amongst our countrymen was this:—"The next event will be the construction of a railway to India by England, how soon, and what is to be the route?" These questions are, on the whole, still unanswered.

Several rival schemes are in the field—unless it may be that the commencement of the construction of the Candahar Railway has decided the line of country that is to be taken up. It sometimes happens in affairs, that when men hesitate in taking a side, and delay in carrying out an enterprise, the force of circumstances steps in and proclaims their inefficiency by deciding for them, and in spite of them. Of these several schemes I shall not now attempt to consider more than two, viz.: first, that of General Chesney and Mr. William Patrick Andrew, *via* the Euphrates Valley and the Mekran coast to Kurrachee, which may be called "the South Persian route;" and, second, that which I more particularly advocate, or "the North Persian route."

The western terminus of the latter line will be at Constantinople, and its eastern terminus at Shikarpore, on the River Indus, about 250 miles in a straight line N. N. E. from the port of Kurrachee. It is impossible, at this stage of the matter, to settle the route from Constantinople through Asia Minor; several directions are suggested for it. Those most in favor seem to be two; that *via* Ismid, Angora, Sivaz, and Arabkir; and a more westerly route *via* Ismid, Karahissar, Konieh, Karabunar, and the Cilician gates. The center of Asia Minor consists of high table land, throwing out ridges and spurs on all sides; it is a rough and difficult country, and is divided from the valleys of the rivers Euphrates and Tigris by the Taurus range of mountains, about which little appears to be known. Mr. Lynch has, however, stated in evidence that Mr. Consul Taylor has discovered a perfectly practicable pass for a railway at Arabkir.

In addition to the terminus at Constantinople, the railway will have a second western terminus, the site of which will be on the coast of Syria, from which point a branch line will be carried to join that from Constantinople, or, in other words, the railway will bifurcate at a point to be named on the southern slopes of the Taurus range, one fork leading from Constantinople, the other from the Levant. The absolute necessity of this last mentioned fork is universally conceded, in order that England may always possess a free and undominated approach to the railway from the open sea; and, indeed, one cannot help coming to the conclusion that the Government, in gaining the island of Cyprus, had for the principal object of its acquisition to protect the Levant terminus, which will be just 130 miles from the harbor of Famagosta in the island.

The port of Swadia, on the Levant, seems to possess advantages as a point of departure superior to those of any one of the other ports recommended. The second fork, then, will commence at Swadia, will pass through the towns of Antioch, of 10,000 inhabitants, and Aleppo, of 70,000; it will cross the Euphrates, between Biredjek and Port William, the latter being the point where Chesney built up his squadron and launched it, having dragged it and all the rest of his *materiel* overland from Swadia; here the river is about 250 yards wide and 15 feet deep; the railway will then run along the slopes of the Taurus, not far south of the towns Orfah, Diabekir, Nisibin, and Mardin, and will intersect the various roads leading south from Asia Minor into Mesepotamia, a most valuable factor in the position. It will then tap that great center of the traffic of a large tract of country, and of population, the city of Mosul, resting on the right bank of the river Tigris, adjacent to the ruins of the ancient city of Nimroud, the scene of Sir H. A. Layard's discoveries; it will cross the Tigris south of the junction of the Greater Zab with that river, pass on by or near to the town of Erbil, cross the Lesser Zab, pass near the towns of Kirkuk and Kefri, where it is 90 miles from

Baghdad, "the City of the Caliphs," and which, by virtue of its large population, extensive trade, and commanding riparian situation, will be worthy of a branch line of that length. At Kefri, it finds itself close to the Persian frontier, and face to face with the "Gates of Zagros," a range known to Sir Henry Rawlinson, which it will cross at a point to be determined. The first town of note met with in Persia, is Kirmanshah; it then passes through Hamadan, which those persons who have read Lord Beaconsfield's "Tale of Alroy," will recollect, and shortly after reaches Teheran, the capital, due south of the axial line of the Caspian Sea, and from the point of view of traffic, the culminating position of the railway in Persia; here it is 70 miles from the Caspian Sea coast, and 550 miles from Tiflis, the Russian military depot of the Caucasus. At Teheran, the railway will draw into its embrace the whole of the Persian east, west, and central traffic—Ispahan being just 300 miles due south—the traffic from the northwest district cities, viz., Choi, Tabriz, and Reschdt, a point on the Caspian being included. The railway thence passes eastward through Scharud, where it is 50 miles from Asterabad, and 70 miles from the nearest point of the River Attrek, goes on by Nischipur 4,000 feet above the sea level, Mesched 3,000 feet across the frontier of Afghanistan, and into Herat 2,650 feet, of which town Colonel Malleson lately gave to the Society of Arts a most vivid graphic and description, and which is 100 miles from the Persian frontier already crossed. At Herat it will no doubt meet "the Candahar railway" before alluded to, and now being constructed. It will pass by the towns Sebzar, Farrah, and Girischk, through Candahar, on to the frontier of the territory of the Khan of Kelat, not through the Bolan Pass, but by a more practicable one to the northwest, and somewhat parallel with it, lately discovered, and which possesses advantages political and constructive superior to those of its venerable rival route; it leaves Quetta 10 miles on its right, passes through the Pischin, towards Gwal, to Durgai, at the foot of the Chapar mountain, the village of Khost, the Hurnai valley, the Nari Pass, Sibi, Mithri, to Jacobabad, and Shikarpore, its termination. Here it will be placed in communication with the whole of the Hindostan railway system, through Lahore northwards, and *via* Bombay to the south, as soon as the gap between Kurrachee and Ahmedabad shall be completed.

Between, and including Swadia and Shikarpore, the railway will thus accommodate about 24 cities and towns of considerable importance, while it is practically safe from the most combative of the Arab tribes, their country lying at the west of the Euphrates; not that these nomads are anywhere to be greatly feared; they cannot be more difficult to manage than the Indians of the American continent, who were similarly somewhat dreaded at first by the promoters of the Pacific Railway of the United States, but who are now easily and effectually held in check.

The route for a railway to India, has now been traced from west to east, or from its termini on the Dardanelles and the Levant, to its junction with the Indian railway system on the Indus; and it is one which will bring with it all those advantages and facilities in which the iron road is so productive, to five great territories, viz., Asia Minor, Mesopotamia, Persia, Afghanistan, and Beloochistan, penetrating them in their most vital parts, and most active centers of national industry; in addition to which, England and the most important dependency of Great Britain—India—are connected by a magnificent artery of communication. But this is not all: the benefits of this railway will not be strained, and exclusively scattered, for the advantage of the countries named. Europe *en bloc* will feel its invigorating and refreshing influences, and to the races of Asia shall be brought that contact with civilization which is their birthright, when for the first time in the history of the world two continents shall become united by clasps of steel; let us endeavor that they may be forged and welded by England. It is certain, it is inevitable, that this, or some similar line of railway, will shortly be added to the category of accomplished facts.

We may, to some extent, arrive at an idea as to what may be the results of its opening, from the results which have followed the opening of the Suez Canal.

The course of trade has rapidly accommodated itself to the new waterway; France and Italy have now got each its line of steamers to India, making frequent voyages; Russia has got its lines of vessels trading from Odessa as far as China, which have almost wholly appropriated the tea trade between those countries, while, as for England, the number of her new ship companies going eastward is legion, and all this has occurred in much less than the ten years that have elapsed since the occasion of the marriage at Port Said of the Mediterranean and the Red Seas, while the Canal brings in a revenue sufficient to pay a handsome dividend on the capital invested. With such facts before us, we may most reasonably expect a profitable traffic from the railway, which will bring London and Bombay within seven days of each other, the cost of traveling by which, assuming the whole distance to be 4,800 miles, and rating the charge for passengers, first-class, at 3d. per mile, to include the expense of food *en route*, will be £60; second class, at 2d. per mile, £40—single fares. Much as we have learned to value railways, and fatigued as we are with the contemplation of the benefits they have conferred upon us, they still have surprises in reserve to delight and astonish us, and it is to the East that we must look for them.

The cost of the construction of a railway through these parts, as a single line of the first-class, with full station accommodation, and passing sidings, is generally computed to reach £10,000 per mile, the land being given *gratis* right through, equal to, from Constantinople to Shikarpore, a distance of 3,800 miles, a total of £28,000,000. The gross take from this capital expenditure, in order to pay five per cent-, should be £2,800,000 per annum, or about £19 per mile per week. The present take of the Indian railways, double and single, is £27 per mile per week, and in the Island of Ceylon it is said to attain the large figures of £54 per mile per week. Whether or not £10,000 per mile will be sufficient to complete the railway, and equip it ready for working, cannot be said with certainty in the present condition of the question. Those persons who are acquainted with the character of the *terrain*, and who are familiar with the cost of the Indian and Russian single line railways, consider that the sum should be sufficient. As high speeds will be required, and heavy loads will have to be carried, the gauge should be that of the English and Continental and Turkish standards—of four feet eight and a half inches. Unfortunately, the Indian gauge is five feet six inches, so that a transfer of cargo will have to be made somewhere *en route*. If the gauge were to be that of the Indian railways, such transfer should take place at Scutari, on the left bank of the stream of the Dardanelles; but by adopting the ordinary English standard, the transfer would take place in Indian territory, which would be preferable. The Russian gauge is differentfrom both of those named, so that a break will also be necessary at junctions with the lines of that country.

Assuming the through distance from London to Shikarpore to be 4,800 miles, the time occupied on the journey, traveling night and day and continuously, would be, at 29 miles the hour, equal to seven days, which is as high a speed as it will be possible to travel the through distance for many years; and with the aid of modern appliances, such as Pullman cars, tatties, unexceptionable *cuisine*, &c., there is no reason why the journey should not be performed at all periods of the year, except, perhaps, two or three of the summer months, quite as comfortably as in going from New York to San Francisco, which is about a six days' ride. Mr. Allport, of the Midland Railway Company, has stated, in public, that he and his daughter having made the American trans-continental excursion, were not in the least fatigued, and had said to each other, on having arrived at San Francisco, that they could have at once started, without discomfort, upon the return journey, if they had felt it to be necessarry to do so.

The principal rival scheme to "the North Persian route," is that *via* the Euphrates Valley and the Mekran coast, which was so ably and so eloquently described in a paper read by Mr. W. P. Andrew, from this place, in February last. He would gladly accept the boon of "a railway to India" by installments, and so directed his attention on that occasion only to that portion of the route lying between the Levant and the head

of the Persian Gulf. Whatever may be the route finally adopted, Persia is the key of the position. Persia consists of but a ring of available country, its central points being a waste. It resembles a finger-ring, moreover, in so far as this, that its jewels are embedded in one segment only, that facing the North-West and North, and those jewels are the cities and towns of Choi, Tabreez, Reschdt, on the southern shore of the Caspian Sea, Hamadan, rather inland, Teheran, the capital, Scharud, and Mesched. There cannot, therefore, be a second opinion, from the point of view of traffic only, as to whether the northern or the southern portion of this ring is to be occupied by "a railway to India;" the inequality of distance between the two routes being inconsiderable. To judge from the minutes of evidence of the committee, the Mekran coast of Southern Persia is almost a *terra incognita.* One may observe scintallating through the fog that envelopes it, one town at 110 miles from the sea, that named Shiraz, worthy of the name, while Bushire, Bender-Abbas, Djask, Girischk, &c., seem to be insignificant places, and mere landmarks dotting the coast to guide the weary traveler as he rides over 1,400 miles of country—which is the distance from Mohammerah, at the head of the Persian Gulf, to Kurrachee, in Scinde. Again, a railway in these parts would be of that most objectionable class of line, "a coast railway." Fed only from one side, it taps only half the country, and one-half of that population, which is the legitimate allowance of a railway well laid out and well placed at first.

It is by this South Persian route, commonly known as the Mekran Coast, that the Euphrates Valley Railway of Mr. W. P. Andrew can alone be extended to India, that is to say, it will pass through 1,400 miles of a district perfectly destitute of traffic, and with only one town of importance in that distance, which is Shiraz. Is it likely, except under circumstances of the most urgent necessity, that the railway to India will ever take up such a hopelessly barren and uninviting country? This is really the weak place in the scheme, and, to all present appearances, that which will be fatal to its adoption.

The Euphrates Valley route commences at Iskanderoon, in the Bay of Issus. It crosses the Beilan range of mountains, 2,100 feet high, at a short distance from the seaboard, passes through Aleppo, along the right bank of the Euphrates, visits the sacred places, Kerbela and Nedjef, and has its terminus at the fine harbor of Grane or Kowait, at the head of the Persian Gulf. Its merits are, the entire absence of engineering difficulties—bar the Beilan range—and the fact that Grane is an unexceptionable harbor, protected, healthy, having good anchorage, good drinking water, and being easily accessible. But, it has its disadvantages; it taps only one great town and center of trade, Aleppo; the places, Kerbela and Nedjef, however, are not to be despised. Well, that gives just three towns of importance along a route of 900 miles. Again, it is only "a fragment of a railway to India," as described by Sir H. Rawlinson, and when the through route to India is to be made, only a fragment of this fragment will be available. A great point made in its favor by its advocates, is this, that a Euphrates Valley railway would be an alternative route to the maritime canal of Suez, and useful accordingly in the event of a stoppage of the latter by an enemy; that, however, ought not to be; and if it shall ever be attempted by Russia, she must first march across the alternative route, and if able to stop the canal, she can, *à fortiori*, stop the alternative. The breaking of bulk at each extremity of this railway of 900 miles in length, would moreover be an insurmountable obstacle in the way of its carrying a goods traffic, upon the carriage of which there would be a saving of time of three days at the most.

When considering the question of a railway to India, its supporters and its pioneers, it would be ungenerous to overlook the part that the indomitable Chesney performed in introducing it. Just 50 years ago he made his first notes as he traveled in the districts concerned, submitted them to the King, received a grant from the House of Commons of £20,000 for the purpose of making surveys, which grant was supplemented by £5,000 from the Indian Government, took his orders from the Duke of Wellington and Lord Ellenborough, and hav-

ing had two small steamers built by Laird, of Birkenhead, and being full of enthusiasm for the enterprise, and buoyed up by the patronage of the King, he sailed from Liverpool on the 10th of February, 1835, in the ship *George Canning*, carrying on board his little iron squadron, stowed in pieces, as well as the *personnel* of the expedition, destined for the navigation and *reconnaissance* and survey of the Euphrates. He is gone, but, I hope, not to be forgotten whenever the truly great enterprise of an improved—and a railway—communication with India is being discussed. Contemporaneous events are worthy of note, as we pass on with the subject. The Liverpool and Manchester Railway was opened in 1830; the charter of the East India Company was abrogated in 1833; and Richard Waghorn established "the overland route to India" in 1834. It was Waghorn's route that caused the collapse of Chesney's *via* the Euphrates Valley. I take the opportunity to pay a humble tribute of respect to the memory of a gallant, generous, and brave spirit, and a born explorer.

The question as to that point on the Levant from which the railway should start, has caused some difference of opinion. Swadia possesses many and probably superior merits to any of the others. It was the port selected by Chesney for his landing; it is the port of the town of Antioch, eleven miles inland, with 10,000 inhabitants; it is irreproachable in the matter of health; it possesses an excellent anchorage and holding ground; it is the only port on the Syrian seaboard from the north down to Beirut that is not backed and separated from the interior by a mountain barrier. Chesney thus describes it:—

"The bay is seven miles wide, and encircled by a mountain girdle of striking grandeur, varied here and there by spots of most attractive scenery. Southward, a wall of rock rises from the valley below the wooded sides and bold peak of Mount Cassius, from which the outlying range of Gebel el Akrab runs eastward, at an elevation of 5,318 feet. Parallel to this bold range is the valley of the Orontes, with the hills of Antioch, showing near its termination; more northward, still forming the opposite horn of the Bay of Antioch, is Gebel Musa, a wooded and picturesque mountain, with the caverns and excavations of Sileucia in its lower slope, which terminates this magnificent panorama. The little town of Swadia, though scarce a mile from our ship, is completely hidden in the dense mulberry plantations which surround it. The scene before us was magnificent; for grandeur, beauty and extent, it could scarcely be surpassed."

The River Orontes rises in the mountains of the Lebanon in about the latitude of Beirut, and flowing north and parallel with the Syrian coast for about 100 miles, it turns sharp to the west, and in a winding course forces its way through a defile in the Swadian amphitheatre, debouching into the sea at the centre of the bay. It is through this defile that it is proposed to carry the railway, upon a mean gradient of 1 in 234, and the gradients will be unexceptionable. The winding river will have to be crossed by bridges several times, and a sea wall must be run out to enclose a harbor, for which there is abundance of stone hard by. Nature has done much for this port, and art must perform her share in making it perfect. General Chesney says of this portion of the question, in his paper read before the British Association, 1857—

"Alexandretta does not promise to answer, on account of the mountains; ancient harbor of Seleucia also condemned, not sufficient depth; but on the south side of the bay of Antioch, a spot selected by Sir John MacNeil, admirably adapted for a safe and commodious harbor of refuge, can receive second-rate line-of-battle ships, and will be as good as the harbor of Kingstown. The spot is three miles south of the river Orontes, and six miles east of the old harbor of Seleucia. Harbor to be made by running out a breakwater on south side of a natural harbor; a perfectly safe and secure harbor for boats, with good holding ground. Stone of finest quality abounds close to where breakwater abuts on land; 1,000 feet of breakwater to be carried out at first instance, vessels of 18 feet draught of water may lie there during first 18 months. Harbor complete, shelter for 30 to 35 vessels; 20 to 40 feet deep; two chain bridges over Orontes necessary."

The other ports on the Syrian coast

are Ayas, Iskanderoon, El Ruad, Latakia, Tripoli, Beirut, Sidon, Tyre, El Arish and Acre. Mercyne also, a port on the Cilician coast of Asia Minor, each of these has got its friends. Iskanderoon, on the south shore of the Gulf of Issus, which is said to possess a good anchorage, is strongly advocated, but it is unhealthy, and is cut off from the interior by the Beilan range of hills of 2,100 feet high, which should be crossed by the railway by a mean gradient of 1 in 21 for 8½ miles from base to summit, and a maximum of 1 in 13 for one mile; also on the other side a mean of 1 in 18 for six miles, and a maximum of 1 in 13 for 2 miles. At the time that this suggestion was made, the Mont Cenis Fell Railway was in fashion, with its gradients of 1 in 12½, and the generally complicated mechanicism of its locomotives, but further experience of that system has not tended to raise it in the estimation of engineers, except in exceptional cases. To carry a heavy passenger and goods traffic over a mountain, where it may be carried on very easy gradients, is hardly likely to be adopted, even with the temptation of a good and cheap harbor to start with. Tripoli has for its spokesman Captain Lovett Cameron. This port is 140 geographical miles in a right line from the city of Aleppo, against 70 miles from Swadia to the same city, which would add 70 miles more than is necessary to the length of the railway. The principal attraction of this port in his eyes is its roadstead, and the facilities that exist for making a fine harbor and a port of magnitude, which will of course cost money. He states that, after leaving the plains that fringe the sea, there are hills around Homs to be crossed, a long viaduct to be built, and a great cutting to be excavated, so that Tripoli presents a rather formidable catalogue of difficulties to be overcome.

The strategical aspect of this great undertaking stands forth prominently, and the route *via* the Mekran coast is pronounced to be the most secure from attack from the north. No doubt it is so at the first blush, and 1,400 miles of it, viz., from Mohammerah to Kurrachee, lying close to the coast, the line could be easily protected by our ships; the most that can be said, however, is that the railway is only somewhat more safe here than on the North Persian route, and not by any means absolutely protected; for instance, at Mohammerah the railway would be only 250 miles from Ispahan and 380 miles from Teheran, cities that could be easily occupied by Russia in the case of a great war with England, in which India was to be the prize. If the railway be carried by North Persia, it becomes a frontier line from Teheran to Herat for 600 miles. As far as Persia is concerned, it would, in this position, be that class of strategic railway which all nations desire to construct as soon as they possess the means. Such a railway is that of the London, Brighton, and South Coast line of railway in England. Russia possesses a similar frontier line, *via* Wilna, Grodna, Warsaw, Rowno, Balta, to Odessa. Other European States are protected in the same way; the object is manifest; such railways afford the means for rapid movements and concentrations between the flanks of an army for either attack or defence. Looking at the north Persian route, from a Persian point of view, it is just the line that country requires for defence; when, in addition to this, it gives her a direct and safe approach to the railway system of India, *via* Herat, Candahar, and Shikarpore, as well as an east and west line connecting the great cities and towns of her own country, there can be hardly a doubt as to her looking to such a railway as an essential member of her network of the future. If it be possible to effect a fusion of the railway interests of England and Persia, so much the better for both. By means of such a combination, we may look forward with hope to the early construction of "a railway to India," without it, the prospect, it must be confessed, is dreary to contemplate. From the railway concession given to Baron Reuter, some few years ago, which was brought about through the intelligent intervention of the Grand Vizier, Mirza Hassein Khan, we may judge of the anxiety of the Persian Government to inaugurate a railway system. This concession, at which, in the words of Sir Henry Rawlinson, "Europe stood aghast," however, came to nothing. According to the same authority, first, the Grand Vizier miscalculated the serious character of the Russian opposition; secondly, England's indifference; and

thirdly, the determined opposition of his own countrymen. Russia showed intense chagrin, because of the negotiation with a rival, and because her trade would be hampered by British *employés* at the Custom-house on the frontier. The merchants of Moscow and Astrakan compound with the Russian officials on favorable terms for duties, and they were alarmed at the prospect of a rigid examination of Customs dues at ports of entry; for these and other reasons they made a resolute stand against the concession. Baron Reuter found it impossible to place the loan, or form a company, and the contract was annulled in 1873.

There is one more consideration which ought not to be omitted, when speaking of our communications with India. Russia has had surveys made of various routes suggested to join her network with that of India, notably with that of M. Lesseps; are we prepared to stand by and allow her to do that which it is our own duty and interest to accomplish? The Rev. James Long says, "a railway from Orenburg to India is popular in Russia, 2,270 miles long, Peshawur being the objective point; the Russian mind is full of it. Hochstetter prefers the Caucasian Russian Railway."

It was stated last week, in the *Standard* newspaper, that the engineers of Russian ways and communications had lately placed before the Emperor, for his approval of one of them, two designs for connecting the Caucasus and Persia by railway, first, from Tiflis *via* Tabreez to Teheran; and second, from the port of Baku, on the Caspian Sea, *via* Reschdt to Teheran.

The distances taken from Kiepert's map of Vorder-Asien, by compasses, shows for the territorial distribution of the mileage of this "railway to India" as follows:

Turkey	1,000	miles.
Persia	1,000	"
Afghanistan	600	"
India	150	"
	2,750	"
Levant fork	250	"
	3,000	"

Twelve months ago it used to be said that Afghanistan would be the chief obstructionist, but twelve months of a period of vast national tension and effort are sometimes productive of vast and unexpected changes, that confound the wisdom of the wise, and reverse the predictions of the prescient. Now, we have changed all that; we have, to all appearances, got the wedge of control and tranquility well into the fastness of these lawless mountaineers, and shall be able to make short work of their interference with a railway; and, indeed, from some quarters we learn that, having heard of the great success of our Indian railways, and the amenities they confer on Indians, they (the Afghans) will be only too happy to have their country tracked by railways, and, in short, they look upon the fact that we have already made 140 miles of the Candahar railway, and that we mean to extend it; as a more powerful reason why they should cry "peccavi," than those of the visits which our projectiles have made them. We may, therefore, dismiss our fears as to Afghan difficulties in the matter of the 600 miles of "a railway to India" that fall to the lot of Afghanistan, and look forward with interest to the period not now far off, when the cry will be heard on the Indus Valley Railway at the Shikarpore station, "Train about to start for Quetta, Candahar, Farrah, and the North."

The kingdom of Persia will carry and care for 1,000 miles of our proposed line. Persia may be held to be the key of the enterprise. Here at once will be our greatest difficulty and our best successes, but our difficulty will not be with the people of the country. Our difficulties will be of a different sort, for it is here we shall first have to deal with Russia. From Persia herself, her Shah, her potentates, and her people, we have nothing but support and approval to anticipate. The country is ripe for the introduction of railways, and, without doubt, will welcome the proposal that they should aid us with all their strength in the construction of a moderately devised design to give their network of the future a start; which must not, however, be of that heroic type which Baron Reuter and Mirza Hassein Khan projected for their acceptance. As to the feelings of Russia in the matter of the Persian instalment of "a railway to India," that is an affair of diplomacy, and it ought to be possible to get it accomplished without paining

her susceptibilities. It is here that the strategical aspect of the design will require the greatest attention, and to this point of the route that the eye of the soldier will be most watchfully directed. No doubt, railways play an important part in warfare, but so they do in matters of commerce and trade, and do we not all look forward with expectation to the period when the only works they shall be called on to do shall be the works of peace. Russia is notably commercial in her tastes and desires, if she is also propagandistic and military, and it is notably from her commercial classes that the call now comes for a railway from Orenburg, or Tiflis, as may be, to Central Asia. Let us strive accordingly that our future rivalries with Russia in that quarter shall be rather commercial than militant, and that the diplomats of both countries may endeavor to solve the difficulties that will arise where dominant interests clash, and that they may crown the edifice by a treaty in which the rights of both nations shall be respected. Possibly, a determination on the part of Persia to connect her great commercial towns and cities by a trunk railway, running from West and East, may yet decide for us the strategy of the case by its entire effacement.

Turkey, and her quota of 1,000 miles, remains to be considered. She has long ago proclaimed her intention not only not to oppose a "railway to India," but to facilitate its construction by all the means in her power. So far, then, as enlisting the approval of the various nationalities through which the route will pass, things may be said to be fairly on the square. There is left the important factor of the approval of the enterprise by the national will at home. England shows signs of arousing, in the presence of the responsibilities that belong to and attach themselves to her. She demeans herself as if she had arrived at the conclusion that a policy of isolation does not pay for a country and a people who are to be found located in every degree of longtitude on the face of the earth, land or water. She has had a run of bad times, coincident with a period of restless languor, such as is not natural to her sturdy and practical mind. She had previously passed through a time of extraordinary, physical, and mental activity, in consequence of the invention of the railway. Other astonishing novelties followed in its wake, the gold discoveries, the telegraph, and the Suez Canal, which latter gave her shipowners and merchants as great a surprise and shock as they have probably ever experienced. New patterns of ships became essential, steam vessels alone were available in the canal, new mercantile principles and practice had to be adopted, smaller stocks of goods than before its opening sufficed for the exploitation of the trade to the East, in consequence of the shorter voyages made. Thus, practically, a considerable addition was made to supplies in hand, and glutted markets were the result, with all the troubles that follow them. But the good ship, though struck by a succession of squalls, has righted and refitted, and prepares for travel through new channels and seas. England is omnipresent in the world, how can she possibly confine her sympathies to the shires and boroughs of these narrow islands? Has she not become aware of this truth, and is she not now bracing herself to face it? as face it she must, or retire from the arena in favor of those who are more worthy of the world's confidence, if such there be. I trust it shall not be so, and that it will be found that the profusion of wealth which she holds has not yet emasculated her sons, as some philosophers have predicted it will inevitably do.

Two hundred and forty millions of natives of India, a gifted and most interesting people in many ways, await our fiat for the opening up of this route. That country has produced great statesmen and legislators, valiant warriors as well as eminent engineers, and architects of the highest capacity and artistic feeling, for where can be found on earth a building to surpass that beautiful and classic pile of marble the Taj-Mehal, and what country has produced a more able and successful ruler than Aurungzebe. I am convinced that there is now a necessity for this railway. I believe in its success. I am confident it will become a source of good fellowship, as it will be a new bond of union between us and them, and it is obvious that it will bring untold guerdons and gifts to lay at the feet of those outsiders who are the denizens of the two most populous of the continents of the globe, that is to say, of Europe and of Asia.

IRON AS MATERIAL FOR ARCHITECTURAL CONSTRUCTION.

By JAMES A. PICTON, F. S. A.

From "The Architect."

It would be fruitless to follow the various modern applications of iron which now extend into every department of industry. Machinery every year more and more supersedes manual labor, and machinery is identified with the use of iron. Whether for good or for evil, this is inevitable. It is the law of development, which no individual effort can prevent or retard. The inquiry remains, what is to be its influence in the future? That it will contribute materially to aid man's power over the material elements of Nature is certain. The moral results lie beyond the province of this paper; but it may be permitted to cast a forward glance at the probable influence of iron in one department, that of architectural construction and design. To what extent can iron be advantageously employed by the architect, and how far will it affect the æsthetic character of his work? All true design arises out of construction. Every style which has attained any eminence owes its effect to the adoption of its essential parts as sources of beauty, rather than to any attempt to conceal them. The use of iron, whether in construction or design, is a new source of power and effect put into the hands of the architect for good or for evil. The adoption of a new material should lead to new canons for its suitable employment, or rather to new applications of the eternal principles of truth and beauty.

Mr. Ruskin, who may justly be called the Corypheus of architectural critics, has some pertinent remarks on the use of iron in architecture. He speaks as follows:—

"Perhaps the most fruitful source of those corruptions which we have to guard against in recent times is one which, nevertheless, comes in a 'questionable shape,' and of which it is not easy to determine the proper laws and limits—I mean the use of iron. The definition of the art of architecture given in the first chapter is independent of its materials; nevertheless, that art having been, up to the beginning of the present century, practised for the most part in clay, stone, or wood, it has resulted that the sense of proportion and the laws of structure have been based, the one altogether, the other in great part, on the necessities consequent on the employment of those materials; and that the entire or principal employment of metallic framework would, therefore, be generally felt as a departure from the first principles of the art. Abstractedly, there appears no reason why iron should not be used as well as wood; and the time is probably near when a new system of architectural laws will be developed, adapted entirely to metallic construction."

This was written in 1849, before the era of great Exhibitions, Crystal Palaces, enormous railway-station roofs, and previous to the great improvements in the manufacture which have so much facilitated the employment of iron. At the present day it is scarcely probable that he would have written as follows:—

"Architecture being in its perfection the earliest, as in its elements it is necessarily the first, of arts, will always precede in any barbarous nation the possession of the science necessary either for the obtaining or the management of iron. Its first existence and its earliest laws must therefore depend upon the use of materials on the surface of the earth—clay, wood, or stone; and as I think it cannot but be generally felt that one of the chief dignities of architecture is its historical use; and since the latter is partly dependent on consistency of style, it will be felt right to retain as far as may be, even in periods of more advanced science, the materials and principles of earlier ages."

Again,—

The fact is that every idea respecting size, proportion, decoration, or construction, on which we are at present in the habit of acting or judging, depends on

the presupposition of such materials, and so . . . it may perhaps be permitted to me to assume that true architecture does not admit iron as a constructive material, and that such works as the cast iron central spire of Rouen Cathedral, or the iron roofs and pillars of our railway stations and of some of our churches, are not architecture at all."

There is more to the same effect, the rule laid down being "that metals may be used as a cement, but not as a support."

"But the moment that iron in the least degree takes the place of stone, and acts by its resistance by crushing and bears superincumbent weight, or if it acts by its own weight as a counterpoise; and so supersedes the use of pinnacles or buttresses in resisting a lateral trust; or if, in the form of a rod or girder, it is used to do what wooden beams would have done as well, that instant the building ceases, so far as such applications of metal extend, to be true architecture."

I have made these copious extracts from a writer whose power and influence we all admit, since nowhere else do we find the objections against iron as an æsthetical element, so clearly and lucidly stated. I would, however, with all modesty, suggest that much may be advanced on the other side. The principal use of metals, including iron, we are here told, is a *cement* for connecting stones together. Every practical builder knows that for this purpose iron is about the worst material that could be employed, its operation being to disintegrate and separate by its oxydation and expansion, and to destroy rather than support.

The unfortunate cast-iron spire of Rouen cathedral I give up as deserving the severest reprobation of the critic, not because of its being iron, but for its tastelessness and incongruity; but what about "the iron roofs and pillars of our railway stations," which we are told "are not architecture at all?" Writing thirty years ago, there was very little in such structures to attract admiration or attention, but look at them now. Westminster Hall, apart from its historical associations, in its wonderful roof exhibits a signal example of skill and beauty combined. This, says Mr. Ruskin, is true architecture. Turn then to the railway station at St. Pancras, with a noble roof four times the span of Westminster Hall, in the construction of which simplicity and skill have produced a result perfectly satisfactory to the eye on the score of sweep of its gigantic curves fills the mind with a sense of harmony and fitness which it is difficult to separate from a feeling of the beautiful. Why are we to deny to structures of this class the claim of being "true architecture?"

Surely the ultimate or radical principal of all true architecture is to use the materials within our reach, in such a manner as will bring out their capabilities most efficiently for strength and commodity, and superinduce upon their employment such decorative forms as the nature of the material may suggest. It is on this foundation that every style which has obtained a footing in the world has been based. What can appear more opposed to each other at first sight than the pure Greek of the age of Pericles, and the pure Gothic, say, of the thirteenth century? Yet diverse as they seem they are equally developments of the principle of truth and adaptation. The materials of both are stone, but the Greek stone being marble, led to a delicacy and refinement of detail of which the northern style was incapable. Given then the material to work with, and keeping in view that the main idea of the one was trabeation or horizontality, and that of the other pointed arcuation, the mind can follow the consistency and adaptation of all the parts, even to the minutest detail. Now can any one doubt for a moment that if iron had been equally available at the two periods in question, the genius which designed the Parthenon or that which soared aloft in the nave of Amiens or the choir of Le Mans would have been equally successful in the design of a metallic structure, especially looking at the beautiful bronze works of the Greeks, and at the rich fancy which characterizes the metal works of the mediæval artists. To prohibit such an attempt, or to limit the exercise of invention, would be "to put a yoke upon the necks" of our rising architects, "which neither our fathers nor we were able to bear." The mischief arises from the attempt "to put new wine into old bottles," to cramp and confine the use of the new material with-

in the lines of the old, with which it is altogether incongruous.

A curious illustration of this tendency may here be mentioned. During the revival of Gothic architecture, about the early portion of this century, the late Thomas Rickman, who did excellent service in explaining and popularizing the study, was employed to design a considerable number of churches in the revived style. Whether owing to the want of skilled masons or from motives of economy, a large portion of the details of these churches were executed in cast iron; tracery, mullions, labels, finials, crockets, even piers and arches. The effect, it need scarcely be said, was poor, thin, and incongruous, and the attempt was an utter failure. If iron is ever to take its place as an independent factor in architectural design, it must be by adopting a new point of departure, ignoring its conventional uses as a mere auxiliary to other materials, and treating it boldly on its own merits and capabilities. The Scylla and Charybdis of architectural art have hitherto been concealment and imitation; concealment of the real construction and imitating in one material the characteristic properties of another.

Let us turn to Mr. Ruskin again. He sets out with the plain principle:

"Know what you have to do and do it, . . . expressing the great principal of success in every direction of human effort; for failure is less frequently attributable to either insufficiency of means or impatience of labor, than to confused understanding of the thing actually to be done. Whatever is in architecture, fair, or beautiful, is imitated from natural forms; and what is not so derived, but depends for its dignity upon arrangement and government received from human mind, becomes the expression of the power of that mind, and receives a sublimity high in proportion to the power expressed. All buildings, therefore, show man either as gathering or governing, and the secrets of his success are his knowing what to gather and how to rule."

These observations are just and true. Let us now endeavor in a general way to apply them to the subject before us. What are the peculiar properties of iron, more especially wrought iron, as a material for building? I should sum them up briefly, as strength combined with lightness and plasticity. These qualities are admirably fitted for construction and decoration in some cases, and not so well adapted in others, and skill and taste are required for their just discrimination and application.

When the scheme for the first great Exhibition in 1851 was launched, designs and proposals of all sorts were broached as to the design and construction of a suitable building. They all fell flat, and were pronounced by the public voice to be cumbrous and unsuitable, being based on the conventional forms of brick or stone building. In a moment of inspiration Sir Joseph Paxton pointed out how the difficulty could be surmounted by a structure of iron and glass. It is easy to ridicule this as a mere gardener's idea of an enlarged greenhouse. When Columbus made the egg stand on its end by giving the shell a slight bruise, the bystanders exclaimed that "anybody could do that," but the same fertile imagination and readiness of expedient led to the discovery of the New World; and Paxton's happy thought has been further expanded and developed so as to furnish a principle of construction now universally adopted in all buildings for a similar purpose. Where a large area has to be covered for bringing together a numerous assembly for a temporary purpose—such, for instance, as the Kibble Palace at Glasgow—there is no material and no mode of construction so economical and effective as the combination of iron and glass. It is, in fact, a tent constructed with durable materials. Modern improvements in the manufacture of iron have rendered this easy which would formerly have been impossible.

But it may be said this is a development in one direction only. What about houses, public buildings, churches, street architecture? I am not preparing a book of designs, nor can I point to a visible embodiment of the tendencies I am pointing out, but in all these departments there is progress already attained and a reasonable prospect of further rapid advance. I have already alluded to the increased employment of wrought iron in the roofs and floors of private buildings, especially in France. Beyond

the merely constructive portion, its use is extending in dome lights, galleries, entrance-doorways, windows, and balconies. In public buildings and churches there has been a timidity in the use of iron for roofs in a manner to combine strength with beauty. The iron roof when adopted is usually concealed. If an ornamental or decorated open roof is designed, it is usually of timber,. except vaulting is introduced. There seems no good reason for this neglect. The adoption of iron might in the first instance require more invention and thought, but the great advantage of security from fire should be a sufficient inducement for the change. In all roofs of great span, the facilities of iron have utterly discarded timber. Street architecture, especially of a commercial character, seems to afford a wide field for the application of iron in a decorative form, but the hand of skill combined with taste will be requisite to prevent its becoming an abortion. Nothing could be more odious or repulsive than long lines of glazed fronts with no relief but flimsy metal bars, looking like houses of cards ready to fall with a breath of wind or the slightest concussion. I have known structures of this kind, perfectly safe in reality, but the outward aspect so flimsy and insecure, that tenants were afraid to trust themselves within the precincts. The true principles are not far to seek. The main lines should not only be strong, but made to appear so, massive if you will, exhibiting weight as well as strength. Within these outlines there may be wide open spaces where the true artist can exercise his taste, and give play to his fancy in a material plastic enough to take any form, strong enough for protection and resistance, and light enough to irradiate the interior even in the murky atmosphere of a city. We are not without hints even from the olden time. In many of the frescoes on the walls of the Pompeian houses, or of the ruined halls on the Palatine, there is a style of architecture displayed which may be the mere fancy of the artist, but which, whilst preserving the leading forms of classical design, exhibits a lightness and grace which would easily serve for models for execution in metal. Many of the shafts of bronze candelabra display the same grace and elegance of form. Amongst the arabesques of Raphael in the Vatican there is a display much of the same character. There is ability enough amongst our modern race of architects, if this course were pursued, to strike out a new path for the progress and adaptation of metallic, and especially wrought iron construction, which would undoubtedly lead to advantages and results not hitherto anticipated. It would be invidious to mention specific cases, but instances might be pointed out in which proceeding somewhat on the lines here laid down, the result has been fairly satisfactory.

THE FUTURE OF CONSTRUCTION.

From "The Building News."

The lintel and the arch have played a by no means unimportant part in the history of architecture, and it may be worth the inquiry how they have been modified by recent constructive expedients, and to what extent they have influenced architectural style. By these terms, in an extended sense, we may designate not only the covering of openings in walls, but the covering of areas; not merely the mode of opening a doorway or window, but the roofing of buildings as well. Of course, the lintel is typical of all forms of trabeate construction that ever existed, from the trilithons and dolmens of prehistoric times, to the perfect structures of Greece; so the arch may be said to represent every form of construction, in which the principle of abutment exists, as when the stones are made to abut upon each other, instead of simply reposing upon the walls. The principle of the arch was known to the Egyptians, as we see by the huge abutting stones over the entrance to the Great Pyramid of Gizeh, and the pointed-shaped ceiling to the sepulchral chamber of the Third Pyramid, which simply consists of large

stones strutted against each other, and the underside slightly curved to a pointed form: but the arch system was the system *par excellence* of the Roman and Romanesque and Mediæval builders, and it is to these developed forms that we generally look for an illustration of its construction.

In short, it may be regarded as a fact that every style has been the outcome, more or less directly, of the lintel or the arch. If we go back to the original forms of arched buildings, we find even a modification of the lintel: the wall at Tiryns, near Mycenæ, and the Treasury of Atreus are rather instances of corbelling, or a succession of horizontal layers of stone covering the opening. They show certainly that the ancients had no clear idea of the real arch, as we now understand it. The above structures are specimens of horizontal arches, such as are met with among all Pelasgic races, in India, and in Central America, and it is an interesting matter for speculation whether or not this form of arch in Greece and in Asia Minor owed its origin to wooden construction, as it undoubtedly did in India and America. In Buddhistic structures, and in latter forms of Hindu architecture, the corbel, or bracket, and the three-stone arch are common features, and the last is a simple compromise of the arch and lintel, which led in time to the more perfect arch of many radiating voussoirs, the top crosspiece becoming the keystone. Important results naturally followed from the discernment of the mechanical principle of the arch; it led to the vigorous but restless architecture of Western Europe, the grand churches of Provence and Aquitania, and the finely-equilibriated structures of the Middle Ages. But the architect of the Renaissance used both forms indifferently, and it is from this condition all modern architecture has been developing. We must not omit to mention here the introduction of another system of of supreme importance in construction, combining both the elements of the lintel and the arch—we mean the truss. As all ancient architecture has arisen from the two former, to the latter we must look for any new outgrowth, and we consider it to be one intimately related with the future of iron. In the discussion upon iron at the Royal Institute the other night, there was, as we anticipated, a decided disavowal of the capabilities of iron among the leading architects. Mr. White and Mr. Street both disclaimed any sympathy with its use, and we may take their sentiment as that of the school of architects they represent. But, while they openly reject iron as a material, they would probably acknowledge its value in combination with other materials. It is significant that many of those gentlemen who have protested against it have employed it in their buildings. As a matter of fact, its use has been forced upon an unwilling profession. The question, however, of architectural style depends so much upon the means of spanning openings and covering buildings, that iron, as a material, will sink before the much more important question it opens, and, it seems to us, the future of architecture will depend largely upon the use architects make of the lintel, or the arch. When it is considered that concrete can be combined with iron in such a manner that each material may exercise its full capability of work: that beams, and floors, and roofs can be constructed so as to form homogeneous and monolithic structures, merely resting their weight upon the walls, it will at once be apprehended that these forms of construction we now regard with repugnance, because they have only been tentatively tried by the engineer in a rough-and-ready sort of way, are only awaiting the thought and refining grace of the architect to make them take their place in the evolution of architectural styles. It is even, moreover, a consideration of weight in determining the question we have put, that the revival of terra-cotta manufacture, especially in large blocks, has a tendency to lead us to the lintel rather than to the arch. The manufacture of iron beams and trussed girders, though chiefly interesting when viewed from the engineering point of view, has led to the recognition of the lintel element. It is at least clear that round and pointed arches do not lend themselves kindly to commercial or domestic buildings, except in a decorative sense, and no architect would consent to use either on a large scale, unless it were properly constructed, and provided with abutments. The smaller decorative arches are simply

lintels, being cut in stone, or cast in terra-cotta. Again, the truss is really nothing more than a constructed lintel; it can be shaped by art into the form of the arch, or into any other pleasing form, while it admits of the utmost economy of material. On the contrary, a constructed arch is always a source of trouble and danger, and modern architects can, consequently, use it only as a subordinate feature in their buildings. The most beautiful arcuated and domical styles, such as those of India, are constructed, as we have seen, upon quite another principle. The dome of the Tomb at Beejapore has been instanced by Mr. Ferguson as a wonderful instance of internal equipoised construction, totally unlike the system employed by the architects of Europe. The horse-shoe arches of Saracenic buildings are really self-balanced arches. Such thoughts as these lead us to the conclusion that the construction of the future will depend more upon the solution of the question we have been discussing than upon the employment of a new material only. It will be a matter of the combinative value of iron, for instance, and the settlement in our own minds of the problem we have hinted that will lead the way to the evolution of a national style, if ever one is possible.

THE THEORY OF MODERN AMERICAN SUSPENSION BRIDGES.

By S. C. Professor CELESTE CLERICETTI, of Milan.

From the Proceedings of the Institution of Civil Engineers.

1. It is well known that the engineers of the United States have found a practical solution of the problem of long-span bridges. It is also known that the solution consists of an improvement of the simple suspension system which prevailed in the first half of the present century, but which has lost credit in consequence of its insufficient rigidity.

The railway bridge constructed on the new principle in 1855 over the Niagara by Mr. Roebling, to whom the innovation is principally due, which measures 250 meters between the towers, and over which locomotives have been running for twenty-five years, is a sufficient proof of the stability of the system, even without mentioning the other five or six bridges, including the last and largest one over the East river, between New York and Brooklyn, having a span of nearly 500 meters between the supporting points.

The new system, besides its principal element, composed of steel or iron wire cables, includes:

1st. A certain number of straight rigid girders, of the ordinary construction, connected with the cables by a series of vertical rods.

2nd. A series of inclined ropes radiating from the saddles and supporting the girder at equi-distant points, leaving unsupported only about the middle third of the same.

Another source of rigidity in the system arises from the cables, which instead of being disposed in a vertical plane, are inclined inwards; and also from a series of horizontal ties, which increase the lateral stiffness and diminish the oscillations from high winds.

Neglecting the inclination of the cables and the horizontal ties, three different elementary structures compose the system just described. First a flexible structure, which is formed by the cable; secondly, an articulated system constituted by the sloping ropes, joined at their lower end by a horizontal tie; and thirdly, an elastic system, the girder.

In the American bridges under consideration it does not appear that the extremities of the sloping ropes are connected by a horizontal tie; they are generally fastened either to the top or to the lower boom of the girder. But it seems to the author that the completion of the articulated system by a horizontal tie situated along the neutral axis of the girder, where it would only be subject to longitudinal tension, would be preferable to the American custom, which has the

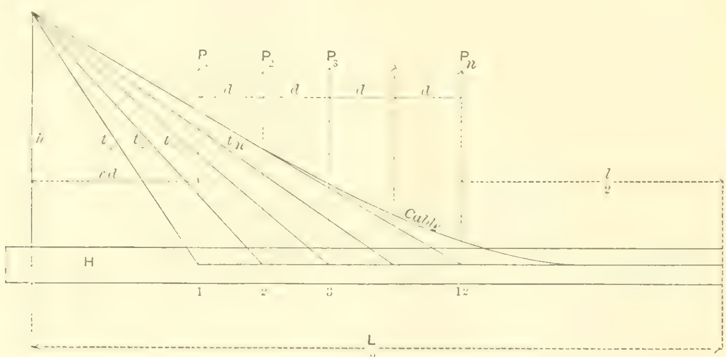
disadvantage of increasing the strains, either of tension or of compression along one of the flanges, producing a corresponding displacement of the neutral axis of the girder.

2. In order to ascertain the conditions of equilibrium of the compound system as defined, the author begins his research by taking into consideration the double structure constituted by a horizontal elastic girder, supported at both ends by the abutments, and at equidistant intervals by inclined ropes, radiating from two points situated on a level on the verticles above the supported ends. The sloping ropes leave part of the girder unsupported towards the middle, which part, in the bridges of this system already erected, varies from one-third to two-fifths of the whole span.

The combined structure is supposed at first to carry a uniform load, distributed over the whole length of the girder, the moment of inertia of which is taken to be constant between two joints, but to vary from one joint to the other.

By the ordinary process of analysis of elastic structures, three consecutive series of equations are deduced. The first series gives the bending moments M_k at any point between two consecutive joints; the second gives the corresponding inclination of the girder, and finally the equations of the third series give the verticle flexure.

By combining the equations of the first series with those of the third, a new series is obtained, which show the following property: the bending moments in any three consecutive joints are connected by the well known theorem of



Clapeyron of the three moments. Calling

M_{k-2}, M_{k-1}, M_k the bending moments of the girder in three consecutive joints;

s_{k-2}, I_{k-1}, I_k the moments of inertia of the girder in the same points;

$_{k-2}$, Is_{k-1}, s_k their vertical displacement from the original horizontal line, passing through the supports;

d =the constant distance of two joints, excluding the middle portion whose length is l;

q =the uniform load on the girder per meter; and finally

E'=the co-efficient of elasticity of the material of the same:

then the general expression arrived at, is

$$\frac{1}{d}\left\{M_{k-2}+4M_{k-1}+M_k\right\}=\frac{6E'}{d^3}\left\{I_k s_k-2I_{k-1}s_{k-1}+I_{k-2}s_{k-2}\right\}=q\frac{d}{2}\cdot \quad (1)$$

3. The principal condition which arises from the combination of the two structures analyzed is evidently this: the vertical displacement of the end of any radiating rope, produced by its elastic elongation, must be equal to the vertical flexure of the girder in the same joint.

Taking into consideration the articulated system, the vertical component of the elastic elongation of the k^{th} sloping rope is easily demonstrated to be, with sufficient approximation,

$$s_k=\frac{R}{Eh}t_k^2 \quad . \quad . \quad . \quad (2)$$

being

R = the maximum stress per square unity of rope section;

E = the coefficient of elasticity of the material of the same;

t_k = the normal length of the rope under consideration.

By introducing the above value in equation (1), and by putting

$$I_k = M_k \frac{H}{2R'} \quad \ldots \ldots \quad (3)$$

H = the constant depth of the girder;

R′ = the maximum stress per square unit of section of the girder. By putting

$$\frac{R}{E} \cdot \frac{E'}{R'} = c \quad \ldots \ldots \quad (4)$$

and calling h the height of the points of suspension, above the neutral axis of the girder, equation (1) becomes:

$$M_{k-2}[3cHt^2_{k-2} - d^2h] - 2M_{k-1}[3cHt^2_{k-1} + 2d^2h] + M_k[3cHt^2_k - d^2h] = q\frac{d^4h}{2} \ldots . (5)$$

This equation contains as unknown quantities only M_{k-2}, M_{k-1}, M_k; therefore by making successively $k = 1, 2, 3 \ldots n$, there will be deduced $(n-1)$ equations with $(n-1)$ unknown quantities, the moment M_n at the last joint near the middle being determined by the author by a different process.

Putting:

$$3cHt^2_{k-1} - d^2h = a_{k-1}$$
$$3cHt^2_{k-1} + 2d^2h = b_{k-1} \quad \ldots \quad (6)$$

$q\frac{d^4h}{2} = C$, equation (5) becomes:

$$M_{k-2}a_{k-1} - 2M_{k-1}b_{k-1} + M_k a_k = C \ldots (7)$$

The series of $(n-1)$ equations deduced from this are then solved, by the method of indeterminate coefficients, by introducing two series α and γ, of which the general expression is:

$$\alpha_k = 2\alpha_{k-1}\frac{b_{n-k}}{a_{n-k}} - \alpha_{k-2} \quad \gamma_k = 2\gamma_{k-1}\frac{b_k}{a_k} - \gamma_{k-2} \quad \ldots \ldots \quad (8)$$

being $\alpha_o = \gamma_o = 1$.

The value of M_{k-1} is then obtained, being

$$M_{k-1} = -\frac{1}{a_{k-1}\alpha_{n-1}} \left\{ C\left(\alpha_{n-k}\sum_o^{k-2}\gamma_x + \gamma_{k-2}\sum_{k+1}^{n}\alpha_{n-x}\right) + M_n a_n \gamma_{k-2} \right\} \quad \ldots \quad (9)$$

The value of M_n deduced separately is

$$M_n = -q\frac{dh}{4} \frac{\dfrac{2d^3}{\gamma_{n-1}}\sum_o^{n-2}\gamma_x + d^3 + l^2}{a_n\left(1 - \dfrac{\gamma_{n-2}}{\gamma_{n-1}}\right) + 3hd(d+l)} \quad \ldots \quad (9')$$

Introducing this value of M_n in equation (9) and making $k = 1, 2, 3 \ \ldots \ (n-2)$, $(n-1)$ all the required moments will be obtained. These moments of flexure are all negative; it follows that, as on the contrary, the moment in the middle of the girder is positive, there are two points of contrary flexure in its curvature. These points are situated in the portion l of the girder, unsupported by the sloping ropes.

The vertical component P of the tension in any inclined rope is a linear function of the moments of flexure in three successive joints, the middle of which is the end of the rope; the general expression is:

$$P_{k-1} = qd + \frac{1}{d}[M_k - 2M_{k-1} + M_{k-2}] \ldots (10)$$

$$P_n = \frac{q}{2}[L - (2n-1)d] + \frac{1}{d}(M_{n-1} - M_n) . (11)$$

L being the total length of the girder.

But the portion of P_{k-1} and P_n which depends upon the moments, or the second term of each expression, being always comparatively small, either plus or minus, a sufficient approximation for practical use is attained by assuming $P_{k-1} = qd = $ constant.

$$P_n = \frac{q}{2}[L - (2n-1)d] \ldots (12)$$

That is to say: the vertical component of the tension on any inclined rope, can be assumed equal to the weights applied to the girder, from the middle of the left, to the middle of the right bay.

When applying these formulæ and the preceding, (10) and (11), it must be remembered that k varies from 1 to n.

The knowledge of the vertical component allows the horizontal component or thrust to be easily deduced, and from any of them the resultant or the longitudinal tension on any inclined rope may be found.

4. In the numerical applications of the summarily recapitulated theory the value of c (4) is assumed by the author to be $\frac{3}{2}$

when both ropes and girders are of iron, on the consideration that for simple tensile stress, as that to which the ropes are exclusively subject, the maximum stress R can be taken at $\frac{3}{2}$ of the corresponding limit R′ of the girder. And even should the girder be of wood and the ropes of wire the fraction $\frac{R}{E} \cdot \frac{E'}{R'}$ can still be assumed $= \frac{3}{2}$, because the value of E′ for wood is about 100.000 kilogrammes per square centimeter, while E for iron is 1,800.000 kilogrammes, so that $\frac{E'}{E} = \frac{1}{18}$. Then, assuming as mean value $R' = 37$ kilogrammes, and $R = 1{,}000$ kilogrammes per square centimeter, it follows again that $C = \frac{1}{18} \cdot \frac{1000}{37} = \frac{3}{2}$ nearly.

The vertical deflection in the middle of the girder is given by the formula

$$s_m = -\frac{5}{384} q \cdot \frac{L^4}{E'I_m} + \frac{1}{E'I_m} \left\{ \frac{dL^2}{8} \sum_1^n Px - \frac{1}{6} \sum_1^n Px^3 \right\} \quad . \quad . \quad . \quad (13)$$

in which I_m is the moment of inertia of the girder in the middle, and

$$\sum_1^n Px = P_1 + 2\,P_2 + 3\,P_3 + \ldots + n\,P_n$$

$$\sum_1^n Px^3 = P_1 + 2^3 P_2 + 3^3 P_3 + \ldots + n^3 P_n.$$

The author has applied the preceding theory to some American bridges, amongst them to the Niagara bridge of 1855. As regards the same, Mr. Malézieux states that the deflection of this bridge, when loaded through all its length by a heavy railway train, does not exceed 25 centimeters. The above formula gives

$$s_m = -479{,}749 \frac{R'}{E'}.$$

The girder being constructed of wood, supposing the maximum stress in the upper and lower flanges to be $R' = 50$ kilogrammes per square centimeter and $E = 100.000$, as before stated, then

$s_m = -0.239$ meter, or 24 centimeters.

In order to explain how this result has been obtained, it is necessary to state that for want of knowledge of the real dimensions of the flanges, and hence of the value of I_m, the author has introduced in (13) for I_m its value as a function of R′ and M_m; hence the expression appears as a function of $\frac{R'}{E'}$.

The author has also deduced some approximate values, which are necessary for the further prosecution of the theory, and which are useful for practical applications. The approximate value of the moment of flexure in the middle of the girder is

$$M_m = +q \frac{l^2}{12} \quad . \quad . \quad . \quad . \quad (14)$$

l being, as already mentioned, the length of the middle portion of the girder, unsupported by the inclined ropes. The approximation given by this formula, compared with the exact one, which is

$$M_m = q \frac{L^2}{8} - d \sum_1^n Px \quad . \quad . \quad . \quad (15)$$

can be judged by the following results:

	Exact (15).	Formula (14).
1. Niagara bridge of 1855 $\frac{M_m}{q} =$	828,622	833,000
2. East River bridge $\frac{M_m}{q} =$	1,907,571	2,338,500
3. Bridge of 150 meters span $\frac{M_m}{q} =$	194,000	208,300
4. Bridge of 110 meters span $\frac{M_m}{q} =$	128,348	133,330

The approximate value of the moment at the end of the middle part of the girder is:

$$M_n = -\tfrac{1}{2} M_m = -q \frac{l^2}{24} \quad . \quad (16)$$

The approximate value of the deflection in the middle is:

$$s_m = -\frac{1}{64} q \frac{l^4}{E'I_m} \quad . \quad . \quad . \quad (17)$$

which, for the Niagara bridge gives, by the same process as before stated,

$$s_m = -538{,}829 \frac{R'}{E'}$$

and for $\frac{R'}{E'} = \frac{50}{100.000}$ $s_m = -0.269$, instead of 0.24 meter.

Remembering that the moment of inertia has been assumed variable from one joint to another, this result can be usefully compared with the corresponding value of vertical deflection in a girder of the same material and length, equally loaded, under the assumption that the moment of inertia is variable. Assuming I to be subject to the conditions that the minimum stress R′ per square unit of cross section of flanges is constant, the author shows that the deflection in the middle would be proportional to $\frac{6}{384}$ instead of $\frac{5}{384}$, which is the value corresponding to a constant moment of inertia. That is—

$$I_m = -\frac{1}{64} q \frac{L^4}{E_m I_m}$$

which, compared with the last one shows that the deflection in the two cases would be as the rate $\left(\frac{l}{L}\right)^4$, so that the influence of the sloping ropes is clearly manifest.

Another result pointed out by the theory, and useful for practical applications, is that the distance of the first joint of the radiating ropes should be greater than the succeeding ones, in order to prevent the reaction on the abutment becoming negative; or, which is the consequence, to prevent the sloping ropes carrying all the weight of a girder, a condition which is realized in all the bridges of the system erected in America, in every one of them the first bay being longer than the others.

5. In the second part of the work, the principal object of which is the determination of the influence of moving loads, the point of departure is the general expression—

$$\begin{aligned} M_{k-1} l_{k+1}[a_{k-1} + h(l^2_{k-1} - l^2_k)] \\ - M_k(l_{k-1} + l_k)b_k + M_{k+1} a_k b_k \\ = l_k l_{k+1} h(C''_k l_k + C'_{k+1} l_{k+1}) \quad . \ . \ (18) \end{aligned}$$

in which the distances of the joints are supposed to be variable, being

$$l_1 \quad l_2 \quad . \ . \ . \quad l_k \quad . \ . \ . \ . \quad l_n,$$

and the distribution of load also variable. In the same formula are

$$C'_k = 2M'_k + M'_{k+1} \quad C''_k = 2M'_{k+1} + M'_k,$$

M'_k and M'_{k+1} being the moments of flexure in the joints k and $(k+1)$ separated by the length l_k, if this portion l_k of the girder is fixed horizontally at both ends. The symbols thus adopted suppose the load to be distributed either on a portion or on the whole length of a bay, the case being excepted in which the load is reduced to a single weight applied at a joint. Calling z the length of the part of bay l_k loaded by p per meter on the left side, so that the remaining portion $(l_k - z)$ is unloaded, the values of C′ and C″ are

$$C' = -\frac{pz^2}{4l_k^2}(2l_k - z)^2,$$

$$C'' = -\frac{pz^2}{4l_k^2}(2l_k^2 - z^2).$$

If, on the contrary, the load is applied to the right side, over the length $(l_k - z)$ then C″ must be changed into C′ and *vice versa*, and z in $(l_k - z)$ in the given values. If the load covers all the bay, then $z = l_k$, therefore,

$$C' = C'' = -p\frac{l_k^2}{4}.$$

The general values of the series a and b are:

$$a_k = 3cHt^2_k - l^2_k h \quad b_k = 3cHt^2_k + 2l_k l_{k+1} h \quad (19)$$

Equation (18) for $k=1, 2 \ . \ . \ n(n+1) \ . \ . \ . \ (2n-1), 2n$, gives $2n$ equations containing as unknown quantities the $2n$ moments at the joints. But, as they also contain in each value of a and b the quantity (4)—

$$c = \frac{E'}{R'} \cdot \frac{R}{E} = \mu \cdot \frac{R}{R'}$$

representing by μ a constant the question would appear insoluble, if the rate $\frac{R}{R'}$ varied from one joint to another, or in the same joint by changing the distribution of the load. However, calculation leads to the result, that P_k acquires its maximum positive value by the same distribution of load for which M_k is the maximum negative, a result in accordance with the ordinary theory of continuous girders, in which the maximum of the reaction on a pier and of the negative moment are due to the same distribution of load. From this and other considerations, it follows that the rate $\frac{R}{R'}$ is constant throughout the whole

length of the girder, whatever may be the distribution of the load.

Once ascertained that $\frac{R}{R'}$ is constant, the next step is to solve the equations deduced by (18), which is done by the process, already mentioned, of indeterminate coefficients, and with the assumption that the distance of the end of the girder to the first sloping cable is $\nu\, d$, d being the equal distance of the consecutive joints, except the middle part, whose length is l.

Owing to the symmetry of the system, the two series of indeterminate coefficients, necessary for the general case, are reduced to one. The expression of M_k for any distribution of load is:

$$M_k = -\frac{h}{a_k \delta_{2n}} \left\{ \begin{array}{l} \delta_{2n-k} d^2 \Big\{ (C''_1 \nu + C'_2) \\ \quad + \sum_{2}^{k-1} (C''_x + C'_{x+1}) \delta_{x-1} \Big\} \\ + \delta_{k-1} d^2 \\ \quad \Big\{ (C''_{2n} + C'_{2n-1}\, \nu) \\ + \sum_{k+1}^{n-1} (C''_x + C'_{x+1}) \delta_{2n-x} \\ + \sum_{n+2}^{2n-1} (C''_x + C'_{x+1}) \delta_{2n-x} \Big\} \\ + \delta_{k-1} l \\ \quad \Big[(C''_n d + C'_{n+1} l) \delta_n \\ + (C''_{n+1} l + C'_{n+2} d) \\ \quad \delta_{n+1} \Big\} \end{array} \right. \qquad (20)$$

The quantities belonging to each single bay are then separated in this expression in order to ascertain the influence of each. On examining the successive values of the series δ, it appears, first that their numerical value increases from δ_1 to δ_{2n}; and then, that while $\delta_1\ \delta_2\ \ldots\ \delta_{n-1}$ are always positive, $\delta_n\ \delta_{n+1}\ \ldots\ \delta_{2n}$ can either be positive or negative, their sign depending upon the quantity

$$a_{n+1} = 3\, c\, H\, t^2{}_n - l^2\, h \quad . \quad . \quad (21)$$

being positive or negative.

If this quantity is positive, then the numbers δ are also all positive. The consequences of this property are the following:

1st. If a_{n+1} is negative, (max $-$) M_k takes place by loading the $(n+1)$ bays at the left, and also the middle portion l, and consequently (max $+$) M_k corresponds to the complementary distribution of load.

2d. If a_{n+1} is null or positive, (max$-$) M_k takes place when the girder is entirely loaded; then (max $+$) $M_k = o$.

Consequently the quantity a_{n+1} may be termed the fulcrum of the question relating to the influence of the moving load on the systems analyzed.

Now the sign of a_{n+1} evidently depends on being (21):

$$3cHt^2{}_n \lesseqgtr l^2 h \quad . \quad . \quad . \quad . \quad . \quad (22)$$

that is, it depends on the value of the rate $\frac{H}{h}$ between the depth of the elastic girder and the height of the suspension towers. It appears then that a proper choice of the rate $\frac{H}{h}$ is necessary as having an important bearing on the greater or less flexibility of the system, the distribution of load corresponding to (max $-$) M_k, and hence the degree of rigidity of the two combined structures depending essentially on the said rate. The expression (21) being simple it appears easy to choose *à priori* a convenient depth of the girder in relation to the height of the towers.

It does not seem necessary that a_{n+1} should be positive. A sufficient degree of rigidity is acquired by making $a_{n+1} = o$, and even this limit should only be realized for railway bridges, while for ordinary road bridges it would be sufficient to assume for a_{n+1} a negative value not far from zero.

If $a_{n+1} = o$, then from (21)

$$\frac{H}{h} = \frac{1}{3c} \left(\frac{l}{t_n} \right)^2 \quad . \quad . \quad . \quad . \quad (23)$$

l being comprised between $\frac{1}{3}$ and $\frac{2}{5}$ of the total span L.

Taking now into consideration the principal suspension bridges of the system, erected in America, it appears that in the Niagara bridge of 1855, which is undoubtedly the most rigid, and the only one constructed for railway use, the rate $\frac{H}{h}$ adopted by Mr. Roebling is nearly equal to the value deduced by making $a_{n+o} = o$, being $\frac{H}{h} = 0.303$ meter instead of 0.363 meter.

In the other bridges the proportion is inferior to the one deduced from (33); hence their rigidity is proportionately less.

6. The necessity for the principal elements of the system being well proportioned to attain sufficient rigidity will also appear from the following considerations. As the lower ends of the radiating ropes are to be connected by a horizontal tie, in order to neutralize the thrust or horizontal component of the tension along the ropes, the equilibrium of the articulated system requires that the sum of the horizontal components should be null. But any irregular distribution of the moving load will produce a horizontal thrust on one side different from that on the other, which difference must necessarily be supported by the girder. Hence, if the girder is not rigid enough, the load on one side will depress that side, but will raise the other, an effect similar to that which takes place in an elastic arch partially loaded. The consequence is that the inclined ropes towards the unloaded side, not being able to resist thrust, will be deflected. If the difference between the movable load and the permanent one is small, the compression on the ropes of the unloaded side will be so trifling as to prevent their being deflected. But the moving load, as for instance on a railway bridge, may be considerable when compared to the permanent weight; hence the necessity of providing a bridge of sufficient rigidity.

By making $a_{n+1}=o$, the theory indicates that the amount of flexure M_k is negative for any distribution of the rolling load; consequently the stress on the inclined ropes is always tension. In this case the difference of intensity between the stresses of two equidistant ropes will always be small; the reaction of the girder necessary to equilibrate the consequent difference of horizontal thrust must also be small. In the Niagara bridge, for instance, in which the condition $a_{n+1}=o$ is nearly fulfilled, it would be impossible, whatever may be the position of the traveling train, for any inclined rope to be deflected.

On the other hand, in the suspension bridge over the Niagara Falls, erected in the year 1869, for the exclusive use of foot passengers, where the unsupported middle portion of the girder is the half of the whole span, 386 meters, the depth of 2 meters given to the girders would be insufficient if the bridge had to be crossed by vehicles.

To prevent the rise of one side of the truss, when loaded, over the other, the engineer of this bridge has wisely introduced a number of guy lines under the girders, connecting them at many points with the abutments.

To complete this part of the theory the author has taken into consideration a discontinuous load on a single bay of the girder, a research which is of practical importance only for the middle part l of the same. The value of a_{n+1} is also, under this point of view, the key of the solution. If it is negative the load must extend only to a certain part of l to produce in a given point the maximum moment; while if a_{n+1} is positive, the maximum moment is produced by the bay being all loaded.

7. In the first two parts of the theory, which have been summarily recapitulated, the object of the author has been to ascertain the conditions of equilibrium resulting from the combination of the articulated with the elastic system. There remains now to be examined the further combination of these two parts with the third and principal part formed by the suspension cable. The research, it is well to state, can only be approximate, as the question would otherwise be extremely complicated. The point in view being essentially the practical application of results, the author refers to the approximate formulæ (14) (16) (17) which seem to be sufficiently exact.

The curve of equilibrium of a cable of constant section supporting only its own weight is a catenary, while if the load is uniformly distributed over the chord it is a parabola. Therefore, if the two different loads are contemporary, the curvature of the cable must be a special one partaking of the two loads mentioned. But as the weight of the cable can only be a fraction of the entire load, it may be, as it is generally admitted, that the curve of equilibrium is a parabola.

Let the origin be taken in the left suspension point, and let x y be the horizontal and vertical co-ordinates of

any point of the cable. Let p be the load per meter of the horizontal chord, L the span, and h the depression of the vertex of the cable below the points of suspension. The rise h of the cable is taken as equal to the height of the towers above the neutral axis of the girder; it is a condition introduced to simplify the calculations; hence the vertex of the cable is tangential to the axis of the girder. The equation of the curve, before flexure, is—

$$y=\frac{4h}{L^2}x(L-x) \quad . \quad . \quad . \quad . \quad . \quad (24)$$

After the deformation produced by the loads, from which the weight of the cable must be deducted, as the flexure produced by the same takes place when the cable is put up, let h' and y' be the values of h and y; the equation or curvature will then be—

$$y'=\frac{4h'}{L^2}x(L-x) \quad . \quad . \quad (25)$$

Let $h'-h=s_c$ be the deflection of the cable in the middle, and $y'-y=s'_x$ the deflection in the point x, y, then, from (24), (25)

$$s'_x=\frac{4}{L^2}x(L-x)s_c \quad . \quad . \quad . \quad (26)$$

In order to find s'_x the ends of the cable are supposed fixed, under the consideration that the change of length of the external portions of cable or anchoring chains produced by the load must be compensated during construction by a proportional rise of the vertex, and because the deformations produced by a change in the initial temperature are not here considered. The approximate length L′ of the parabola whose chord is L, is—

$$L'=L+\frac{8h^2}{3L}-\frac{32}{5}\frac{h^4}{L^3}+\&c.,$$

or, with sufficient accuracy:

$$L'=L+\frac{8h^2}{3L} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

As the length of the chord is invariable, and as $d(h)=s_c$, it follows that

$$d(L')=\frac{16}{3}\frac{h}{L},$$

hence:

$$s_c=\frac{3}{16}\frac{L}{h}d(L') \quad . \quad . \quad . \quad (28)$$

The cross section of the cable being constant, while the stress varies from one point to another, the consequence is that the specific stress cannot be constant. Let a be the angle between the tangent in the point x y with the horizon, and T the tension in the same point, being Q the constant horizontal thrust. Then—

$$T=\frac{Q}{\cos a},\ Q=\frac{pL^2}{8h}\cos a=$$

$$\frac{1}{\sqrt{\left\{1+16\frac{h^2}{L^4}(L-2x)^2\right\}}} \quad . \quad . \quad . \quad (29)$$

Consequently

$$T=\frac{pL^2}{8h}\sqrt{\left\{1+16\frac{h^2}{L^4}(L-2x)^2\right\}} \quad . \quad . \quad . \quad (29')$$

If an element ds of the curve is subject to the elongation d^2s, then, from a well known formula,

$$d^2s=\frac{ds}{E_cF_c}\frac{Q}{\cos a},$$

F_c being the section of cable, and E_c the coefficient of elasticity of its material, and

$$ds=\frac{dx}{\cos a},$$

the total variation $d(L')$ of the cable's length will be:

$$d(L')=\frac{2Q}{E_cF_c}\int_0^{\frac{L}{2}}\frac{1}{\cos^2 a}dx,$$

substituting the value of $\overline{\cos^2 a}$, and integrating between the given limits,

$$d(L')=\frac{Q}{E_cF_c}\left\{L=\frac{16h^2}{3L}\right\},$$

when, from (27),

$$d(L')=Q\frac{2L'-L}{E_cF_c},$$

otherwise, by putting $\frac{Q}{F_c}=R_c$ it follows that

$$d(L')=\frac{R_c}{E_c}(2L'-L) \quad . \quad . \quad (30)$$

By introducing this value in (28)

$$s_c=\frac{3}{16}\frac{L}{h}\frac{R_c}{E_c}(2L'-L) \quad . \quad . \quad . \quad (31)$$

and finally, from this and (26) it follows that

$$s'_x=\frac{3}{4}\frac{R_c}{E_c}\frac{2L'-L}{h}x\frac{(L-x)}{L} \quad . \quad . \quad . \quad (32)$$

8. An approximate value of the vertical flexure of the girder in the middle of its length has already been given (17); still, in order to render more explicit the influence of the quantity a_{n+1} (21) on the flexibility of structure, the author proceeds as follows:

Considering the middle portion l of the girder, unsupported by the ropes, uniformly loaded by q per meter, being I_m the constant moment of inertia, the differential equation of the deformed axis is—

$$E_m I_m \frac{d^2y}{dx^2} = M_n + q\frac{l}{2}x - q\frac{x^2}{2} \quad . \quad . \quad . \quad (33)$$

which, as already stated, has two points of contrary flexure, determined by the condition

$$E_m I_m \frac{d^2y}{dx^2} = o.$$

Introducing for M_n the approximate value (16), and calling the distance between the points mentioned l_o, then

$$l_o = 2l\sqrt{\frac{1}{6}} = 0.816l.$$

Integrating (33), and deducing the constant, which is

$$C = -\frac{1}{24}ql^3 - M_n\frac{l}{2},$$

it follows that

$$E_m I_m \frac{dy}{dx} = M_n\left(x - \frac{l}{2}\right)$$
$$+ q\frac{l}{4}x^2 - q\frac{x^3}{6} - q\frac{l^3}{24}.$$

Integrating again, calling y_n the deflection of the origin $(x=o)$ where the moment of inertia is I_n, the preceding becomes:

$$E_m(I_m y_m - I_n y_n) = M_n\left(\frac{x^2}{2} - l\frac{x}{2}\right)$$
$$+ q\frac{l}{12}x^2 - q\frac{x^4}{24} - q\frac{l^3}{24}x.$$

The deflection y_n is produced by the elongation of the nth sloping rope, and the corresponding value is given by (2) or

$$y_n = \frac{R_t}{E_t h}t_n^2,$$

where E_t and R_t are the coefficient of elasticity and the maximum specific stress convenient to the wire of the ropes.

By substituting this value in the above equation, and calling the deflection in the middle of the girder s_m, the value of s_m is:

$$E_m I_m s_m = -M_n\frac{l^2}{8} - \frac{5}{384}ql^4 + R_t I_n \frac{t_n^2 E_m}{h E_t}.$$

Calling R_n the maximum specific stress in the girder at the point where the moment is M_m, being H the constant depth of girder, then, from the general equation between the moment of resistance and the moment of rupture,

$$R_n = M_n \frac{H}{2I_n},$$

which, introduced in the preceding equation, together with the approximated value of M_n (16) becomes:

$$E_m I_m s_m = -\frac{3}{384}ql^4 - \frac{1}{48}ql^2\frac{H}{h}t_n^2 \frac{R_t}{R_n}\frac{E_m}{E_t}.$$

Considering now that in absolute value, that is, not considering the sign of the moments, $M_n = \frac{1}{2}M_m$, and also that the moment of inertia is constant along the span l, being I_m, it follows that R_n will be $\frac{1}{2}R_m$. By substituting this value and remembering (4) that

$$\frac{E_m}{R_m} \cdot \frac{R_t}{E_t} = c \quad . \quad . \quad . \quad . \quad . \quad (34)$$

the preceding gives:

$$E_m I_m s_m = -\frac{1}{384}q\frac{l^2}{h}\left[3l^2h + 16cHt_n^2\right] \quad . \quad (35)$$

The quantity a_{n+1} must now be recalled (21); or $\quad a_{n+1} = 3cHt_n^2 - l^2h.$

Remembering that if this quantity is null or positive, (max—) M_k takes place when the girder is completely loaded; and that the girder possesses a sufficient degree of rigidity if a_{n+1} is null, or else a small negative value, then

$$H = \frac{l^2h}{3ct_n^2}k \quad . \quad . \quad . \quad . \quad . \quad (36)$$

or

$$a_{n+1} - l^2h(k-1),$$

being k a fraction not far from unity, and whose maximum is $k-1$. Putting the value (36) in (35)

$$s_m = -\frac{3}{384}q\frac{l^4}{E_m I_m}[1 + 1.78k \quad . \quad (37)$$

which, for $k=0.6$ nearly, gives the approximate value (17)

$$s_m = -\frac{1}{64}q\frac{l^4}{E_m I_m}.$$

Putting now in (36) the value

$$I_m = M_m \frac{H}{2R_m},$$

and for M_m the value (14) the deflection becomes:

$$s_m = -\frac{3}{16}\frac{l^2}{H}\frac{R_m}{E_m}[1+1.78k] \quad . \quad . \quad . \quad (38)$$

which can be given under another form, in order to show more clearly the influence of k. Putting the value of H (36), the last gives:

$$s_m = -\frac{9}{16}\frac{c}{h}t_n^2 \cdot \frac{R_m}{E_m} \cdot \left\{\frac{1}{k}+1.78\right\}\frac{1}{k} \quad . \quad (39)$$

which shows how s_m decreases by increasing k, that is to say, the rate between the real depth of the girder, and the depth which is deduced by making $a_{n-1}=a$.

9. The first condition which must be fulfilled, as arising from the combination of the cable with the girder, is the following: whatever may be the distribution and the intensity of the load, the deflection of the vertex of the cable must be equal to that of the middle of the girder. That is to say, $s_m = s_c$; or by (31) and (37):

$$\frac{R_c}{E_c}\frac{L}{h}(2L'-L) = \frac{R_m}{E_m}\frac{l^2}{H}[1+1.78k].$$

Putting

$$\frac{E_c}{R_c} \cdot \frac{R_m}{E_m} = a \quad . \quad . \quad . \quad . \quad . \quad (40)$$

the preceding equation gives

$$h = \frac{HL}{al^2}(2L'-L)\frac{1}{1+1.78k}.$$

For the practical use of this formula, the approximation given by assuming $L'=L$ is sufficient: therefore

$$h = \frac{H}{a}\left(\frac{L}{l}\right)^2 \frac{1}{1+1.78k} \quad . \quad . \quad . \quad (41)$$

10. A second condition to be fulfilled is that the depth of the girder H should not be less than the limit beyond which its own weight would produce the maximum allowable specific stress R_m in the booms, otherwise the girder would not contribute to the rigidity of the system, especially in its middle part, and as a static element it would be little more than a parapet. This condition is easily represented.

Let ω be the cross section of one of the flanges or booms of a girder in the middle of its length; then the volume of the two flanges together, for 1 meter in length will be $2\,\omega$, which will nearly be the complete volume of the portion of girder considered, because the shearing stress is null in the middle when the load is uniform, and always small under other conditions of load. Still, as it is necessary to complete the trellis, two diagonals at least and a vertical rod must be introduced to join the booms. Then it may be admitted that the volume of these parts in the middle and for the length mentioned is about $\frac{2}{5}$ of the volume of a flange; assuming the diagonals to be inclined at 45°, and calling π the specific weight of the material, the weight of 1 meter in length of the girder in the middle will be

$$2.40\,\pi\,\omega.$$

Recalling the approximate value (14) of M_m, then:

$$\omega = \frac{q}{12}\frac{l^2}{H}\frac{1}{R_m}.$$

Let q_o be the weight of a length of one meter of girder, in the middle of its length, then from the two last expressions

$$q_o = \frac{2.40}{12}\pi \cdot q \cdot \frac{l^2}{HR_m}.$$

and by putting

$$\frac{q}{q_o} = n \quad . \quad . \quad . \quad . \quad . \quad (42)$$

and deducing H

$$H = 0.20\,\pi \, . \, n\frac{l^2}{R_m} \quad . \quad . \quad . \quad . \quad (43)$$

the minimum value of which, for application, should be the corresponding $n=1$, in which case the girder will only support its own weight; any other load would increase the stress in the booms beyond the limit R_m.

11. A third condition requires that every part of the combined structure should be so proportioned as to determine in the whole a state of sufficient rigidity. This condition has already been treated, and found to be represented by (36)

$$H = \frac{l^2 h}{3ct_n^2}k,$$

the maximum of k being $k=1$, as already stated.

Equalizing the three values of H (36), (41), (43), it follows that

$$ha(1+1.78k)\left(\frac{l}{L}\right)^2 = 0.20\,\pi \,.\, n\frac{l^2}{R_m} = \frac{h}{3c}\left(\frac{l}{t_n}\right)^2 k.$$

The first and third of which give

$$t_n^{\,2} = \frac{k}{3ca}\,\frac{L^2}{(1+1.78k)} \quad . \quad . \quad . \quad (44)$$

The second and third

$$t_n^{\,2} = \frac{k}{0.6c}\,\frac{hR_m}{\pi n} \quad . \quad . \quad . \quad . \quad (45)$$

And from these two the following is deduced:

$$h = \frac{1}{5}\,\frac{\pi n}{a}\,\frac{L^2}{R_m}\,\frac{1}{1+1.78\,k} \quad . \quad . \quad . \quad (46)$$

The length of the longest inclined rope is given by

$$t_n^{\,2} = \left(\frac{L-l}{2}\right)^2 + h^2,$$

which, placed in (44) gives:

$$l = L - 2\sqrt{\left\{\frac{L^2k}{3ca(1+1.78k)} - h^2\right\}} \quad . \quad . \quad (47)$$

If the cable and the sloping ropes are both constructed of the same material, and if $R_t = R_c$, that is to say, if the maximum specific stress per square unit of section is also taken to be equal in both, or else if $\frac{E_c}{E_c} = \frac{R_c}{R_t}$, then by (34) and (40) is obtained c $a=1$; hence

$$l = L - 2\sqrt{\left\{\frac{L^2k}{3(1+1.78k)} - h^2\right\}} \quad . \quad . \quad . \quad (48)$$

And when the rate k is taken $=1$

$$l = L - 2\sqrt{\left\{\frac{L^2}{8.34} - h^2\right\}}$$

12. The expressions thus obtained contain the principal geometrical elements of the three combined structures, and the conditions which they must satisfy, in order that the whole may possess sufficient stability; therefore they enable convenient proportions to be assumed between the essential parts of the system.

Formula (46) gives

$$L = 5a[1+1.78k]\frac{R_m}{\pi}\left(\frac{h}{L}\right)\frac{1}{n}$$

which enables the largest possible span to be deduced, or a practical limit of length consistent with the rigidity of the system, and with given limits of specific stresses in each structure.

In fact from the expression obtained, it appears that L increases by increasing k, and also that L is inversely proportional to n. Now the maximum of k is (36) $k=1$, in which case the moments of flexure of the girder are always of the same sign, and consequently the rope cannot be deflected; and the minimum value of n is also (42) $n=1$, in which case the weight of the girder will, by itself, produce the maximum allowed stress per square unit of the given material. Putting then $k=n=1$

$$\max L = 13.90\,a\,\frac{R_m}{\pi}\left(\frac{h}{L}\right).$$

Suppose the case of a wrought-iron girder, then $\pi=7800$ kilogrammes per cubic meter, and $R_m=8{,}000{,}000$ per square meter of section, a limit of stress which should not be surpassed by flanges or booms of an elastic girder. Then follows

$$\max L = 14256.40\,.\,a\,.\left(\frac{h}{L}\right) \quad . \quad . \quad . \quad (49)$$

For extraordinary spans the cables must be made of steel wire, like those adopted for the East River bridge; the rate between the coefficients of elasticity of steel and iron may be assumed at $\frac{5}{4}$, that is to say

$$\frac{E_c}{E_m} = \frac{5}{4}.$$

Finally, the rate between the maximum specific stresses in the iron girder and the steel cable may be deduced by assuming the mean values corresponding to the limit of elasticity of both materials, or $R_m=15$ and $R_c=30$ kilogrammes per square millimeter. Then $\frac{R_m}{R_c}=0.50$; hence from (40)

$$a = \tfrac{5}{4}\cdot\tfrac{1}{2} = 0.63.$$

Substituting this value in (49) it follows that:

$$\max L = 8981.53\left(\frac{h}{L}\right).$$

Taking $\frac{h}{L}=\frac{1}{10}$, a rate which has not been surpassed for large spans by any

suspension bridge yet constructed, the result is:

$$\max L=898.15 \text{ meters, or } 900 \text{ meters.}$$

As for the length of the middle unsupported part of girder, it follows from (48) that $l=276.80$ meters.

The maximum limit of practical span thus obtained is interesting from a singular coincidence. Mr. Malézieux states that Mr. Roebling, the inventor of the combined system under analysis, in a report addressed to the Council of Administration of the East River Bridge Company, declares that the span of the new suspension bridges could be increased without danger to 900 meters.

13. In order to appreciate by comparison the influence which the combination of the three structures has in relation to the maximum span, the author proceeds to deduce a corresponding limit for an ordinary suspension bridge.

Let p be the load per meter of chord, excluding the weight of the cable, ω the cross section of the cable, and π the specific weight of a cubic meter of the material. The greatest tension in the cable will by (29′) be obtained. Putting $x=o$

$$T=(p+\omega\pi)\frac{L^2}{8h}\sqrt{\left\{1+\frac{16h^2}{L^2}\right\}}.$$

Calling R the specific stress per square unit of cross section, it follows that

$$R\omega=(p+\omega\pi)\frac{L^2}{8h}\sqrt{\left\{1+\frac{16h^2}{L^2}\right\}},$$

from which

$$\omega=p\frac{L^2}{8h}\frac{\sqrt{\left\{1+\frac{16h^2}{L^2}\right\}}}{R-\frac{\pi L^2}{8h}\sqrt{\left\{1+\frac{16h^2}{L^2}\right\}}}.$$

By putting $h=k'$ L and deducing L

$$L=\frac{8\omega Rk'}{(p+\omega\pi)\sqrt{[1+16k'^2]}} \quad . \quad . \quad . \quad (50)$$

The required limit of span evidently corresponds to $p=o$: then

$$\max L=8\frac{R}{\pi}\cdot\frac{k'}{\sqrt{1+16k'^2}},$$

which result is identical with that given by Navier.

Taking $R=20$ kilogrammes per square millimeter, $\pi=7800$ and $k'=\frac{1}{10}$, then

$$\max L=2209 \text{ meters.}$$

The conclusion is, that the condition of rigidity necessary for the new suspension bridges reduces to less than half the greatest possible span, corresponding to the rate of $\frac{1}{10}$ between the rise and chord of the cable.

The comparison may also be made, by assuming in both cases the same value of h. Putting in the last expression $h=\frac{900}{10}=90$ meters, which can be considered as a practical maximum, or $k'=\frac{90}{L}$, the result is

$$L=1500 \text{ meters nearly.}$$

Consequently, at the limit of 900 meters the girder would only bear its own weight against a given limit of maximum specific stress, and all the remaining load would be sustained by the cable. Beyond this limit the bridge could not be called rigid, and the load which the cable would be able to bear, besides its own weight, progressively decreases, until at the limiting span of 1500 meters, together with the rise of 90 meters, the extra load would be null, and its own weight would induce in the steel cable a stress of 20 kilogrammes for each square millimeter of cross section.

Sidney Exhibition.—The admissions to the "Garden Palace" during the time it was opened exceeded the most sanguine expectations, being about 1,022,000, without including the closing day. The amount received for admissions and concessions was about £45,000. This sum, though not quite equal to the original estimate of £50,000, would probably defray the ordinary working expenses of the exhibition. The total attendance was regarded as unprecedented, considering the sparse population of this great colony, and the distance from the other Australian colonies and other parts of the world. The number of judges was 204, besides the 100 judges at the auxiliary shows of live stock, wool, &c., and shows illustrating the vegetable kingdom. There were 7,070 awards sent in by the judges, and their reports will be published in a volume.

THE STRUCTURE OF STEEL INGOTS.

By D. K. TCHERNOFF.

Translated from Revue Universelle de Mines.

I.

Among all the materials which satisfy the needs of industrial pursuits, iron in its various forms plays a predominant part.

When metallurgy could not afford the necessary means to produce steel of good quality, and in sufficient quantity, iron, either cast or wrought, satisfied the greater part of the wants of industry. The methods of manufacture of the two forms are essentially different. The difficulty of fusing pure iron, together with the want of proper means to melt it, necessitated a recourse to the complicated and expensive operations of puddling, piling, and the like, with a great expenditure of fuel and the employment of powerful mechanical contrivances. The relative ease of fusion of cast iron permits us to substitute for the difficult work on the metal the lighter labor on softer material, such as wood, clay or sand. That is, in order to obtain an object of the most capricious form in iron, it suffices to make a model of it in wood, clay, or other analogous material; to make its impress in fine sand, and then to pour in the melted metal, which in cooling will have the desired shape and size. Of mechanical labor there remains only the trimming of the edges and the dressing of the surface. The larger portion of castings require no other finishing, and this process, compared with the others, is so simple, that it is always followed, unless circumstances prevent.

When the method of preparing steel cheaply, and of any desired quality and quantity, became a regular industry, the casting of various forms in steel would appear to be a direct consequence of progress in the art of founding. Of the numerous experiments made on casting steel in sand or metal moulds, a few only were crowned with success; especially did they fail in the case of the low steels. The defects were chiefly blow-holes or cavities arising from shrinkage, and sometimes cracks which appeared at the surface. On the other hand, the composition of the steel would not permit easy working of the product obtained. From these causes steel-makers limit themselves to casting ingots of the simplest possible shape, and then resorting to mechanical processes to obtain the desired forms.

Although the obstacles to be overcome in casting steel in moulds are great, yet the pursuit of this end should not be relinquished, in view of the enormous advantages to be gained. Success in this direction depending before all upon exact knowledge of the obstacles to be overcome, we can regard with interest all knowledge of the defects which appear in steel castings.

For this purpose take the most simple form, that of the cylindrical ingot, of which Fig. 1 represents a section. Instead of a compact mass, we find that the ingot contains a great number of cavities. On the right hand side we observe, beginning at the surface, where the ingot was in contact with the mould, numerous blow holes penetrating more or less to the interior of the ingot, according to the conditions in which it flowed in the mould, and depending upon the quality of the steel and the character of the surface of the ingot, whether rough or not.

In the upper part of the ingot is a large cavity of irregular conical shape, extending down along the axis. This cavity, with friable sides, forms a funnel around which the metal is pierced with little cavities. This friable character extends along the axis much below the extremity of the funnel, and includes some tolerably large cavities. Away from the axis of the ingot this character gradually diminishes, and finally disappears, so that a certain thickness of metal between the friable part and the rough exterior is a compact mass.

Under certain circumstances, which we shall discuss further on, we find but few cavities near the outer surface of an ingot cast in a mould. Then the rough surface is replaced by a prismatic structure. (See the left side in Fig 1.)

Examining the neighborhood of the fracture, we find that the prismatic layer is composed of an assemblage of irregular prisms, perpendicular to the exterior surface. The cohesion of the prisms among themselves is not very great, so that the ingots exhibit a parallel lined structure, and break most readily along the surfaces of contact of these prisms; the fracture having a silvery but dull appearance.

The prismatic layer is succeeded by a granular layer, more or less developed, that is to say of an assemblage of grains irregularly polygonal in shape, with a dull silvery white surface, resembling that of the needle-shaped prisms described above. After this granular layer comes a thickness of compact metal having a brilliant fracture; then we pass to the zone in which the friability increases regularly to the axis of the ingot.

We will discuss each of the conditions mentioned above.

The most ordinary defect is the conical cavity, which proceeds from the contraction of the metal in passing from the liquid to the solid state. The form of this cavity is in correlation with the conditions of cooling. The cooling and hardening, consequent upon cooling at the surfaces, begins without doubt at the bottom. As the upper portions fill the spaces left by the contraction of the lower ones, the form of the cone is easily explained. The appearance of the funnel-shaped cavity is so well known that it would be superfluous to describe it in detail.

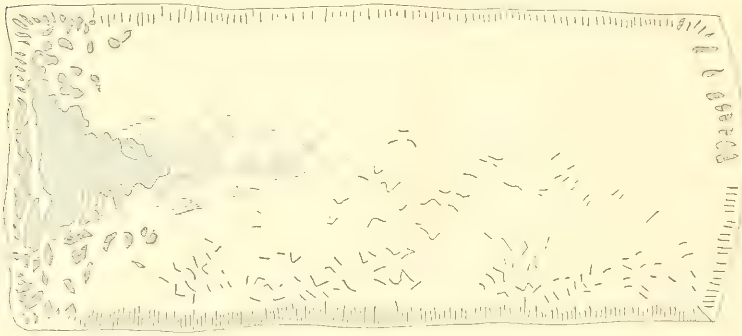


Fig. 1.

The researches of many metallurgists have, for a long time, been directed to the cause of the bubbles which are found in the steel ingot. It cannot be said that investigations thus far have resulted in a general agreement as to the origin of gas in the liquid steel. Some claim it is simply a solution of gas held by the melted metal; others that the gas is the result of chemical reactions between the liquid metal and the material of the crucible lining that contains it; others again attribute the origin of the gas to the mutual reaction of the constituents of the metal and the oxygen of the furnace or the exterior air.

We will not stop to criticise these opinions, each of which is based on facts which cannot be entirely ignored. But it is necessary to add that the causes indicated may act in such way that the gases contained in it result from their combined or simultaneous action.

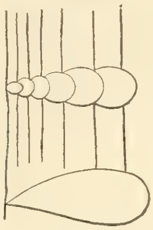
The one thing not disputed is, that the greater part of the gas disengaged is oxide of carbon, and that the time it is set free is the moment preceding the passage of the steel from the liquid to the solid state.

It is proper to conclude that the setting free of the gas from the liquid steel is governed by the same laws as the disengagement of gases, in general, from

liquids that hold them in solution. In steel, therefore, as in other liquids, it is most strongly manifested at the moment of shaking or pouring off the liquid. Thus the pouring of the charge from a Bessemer converter into the ladle, or from that into the ingot mould, is attended with a brisk ebullition produced by the escape of large volumes of gas.

The continued repetition of the operation of pouring would result in the elimination of the gas, if we did not fear the metal would cool too much, and if we could at the same time provide against the oxidizing action of the air.

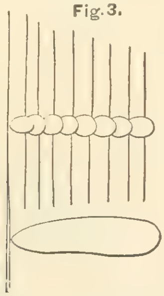
Fig. 2.



The moment the steel begins to cool in the mould, bubbles of gas form and attaching themselves to the sides of the mould harden.

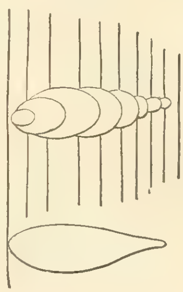
The bubbles of gas forming in the mass of liquid would increase rapidly, being reinforced by the store of gas throughout the liquid; but as owing to the cooling influence of the sides of the mould, the layer of hardened metal is constantly increasing in thickness, the enlargement of the bubbles can only take place in a direction perpendicular to the sides of the mould. At the same time the form of the bubble will vary according to the relative velocity of its enlargement, and depending upon the increase in thickness of the layer of cooled metal. If the enlargement of the bubble is rapid, its diameter increases with its distance from the side of the mould, and it will take the form of a cone with a hemispherical base turned towards the center of the ingot (Fig. 2). When the bubble grows very rapidly the convex part sometimes detaches itself and floats. If the enlargement increases regularly with the cooling, the bubble takes the form of a cylinder with a hemisperical base (Fig 3). If, finally, the thickness of the hardened layer increases faster than the enlargement of the bubble, then the latter, although growing longer, contracts in diameter and terminates in a conical point (Fig. 4). Bubbles of this latter form are very rare.

Fig. 3.



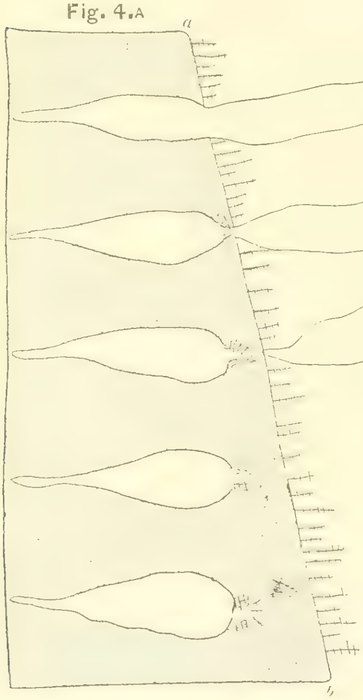
As the mould becomes filled, the pressure of the liquid metal on the lower layers constantly increases, diminishing at the same time the escape of the gases, and consequently arresting the growth of the bubbles in the lower portions of the ingot. The bubbles closing, the next layers of metal which solidify are compact and free from cavities, unless a new disengagement of gas is produced by an accidental fall of pressure. It may be added here that when the bubbles close, there is formed at the top a "funnel of contraction" lined with needle-shaped projections of which we will speak further on. It follows then, that if it were possible to prevent the formation of the first bubbles, which attach themselves to the first molecules of solidified steel, against the sides of the mould, the hardened crust would be free from spherical cavities, and the bubbles forming, not adhering to the sides would float to the surface, and the ingot would have a compact exterior. The phenomenon of adhesion of the molecules of

Fig. 4.



steel to the sides of the mould is analogous to the wetting of a solid by a liquid; the higher the steel is heated, the less will the sides of the mould be heated during the flow; on the other hand the more refractory the material of the lining of the mould, and the poorer its conducting power, the less will be the chance of its being wet by the liquid steel, and of the molecules adhering to it. We may conclude, then, that hot steel, not wetting the sides, would give in a metallic mould an ingot free from cavities on its outer surface; and that steel so hot as not to wet the sides of a

Fig. 4.A

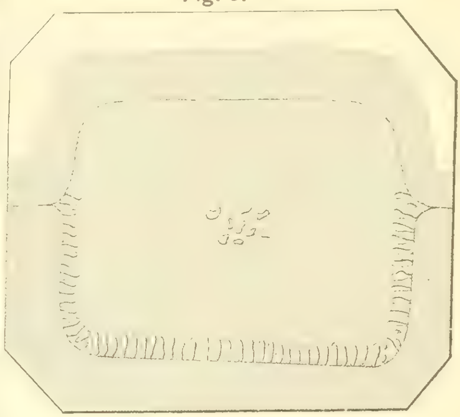


mould of refractory material will give a compact mass, while in a metallic mould the ingot would present bubbles.

An interesting experiment is performed by pouring steel of a medium temperature into a mould made partly of iron and the rest of sand. An ingot is obtained always porous on the metallic side, and altogether compact on the side next the sand lining. Figure 5 represents a section along the side of such an ingot, drawn to about one-eighth of the natural size.

The disengagement of the bubbles occurs at the instant of pouring or immediately after, while the gas can easily escape into the air, in part from the free and uncovered surface of the liquid, and partly in the form of bubbles that rise to the surface and break while the steel is yet liquid. When a crust begins to form the escape of gas is restrained. At the same time the absorbent power of the steel is lessened by reason of the lowering of the temperature; the gas accumulates under the crust, acquiring considerable elasticity, thereby tending to prevent the growth of the bubbles in the upper portions of the ingot. The bubbles previously formed are closed in by the hardened exterior layer, so that the escape of gas is nearly arrested. If the solidified layer is not very firm it will happen that the gas will force an

Fig. 5.



opening, and the steel and gas escaping together will form a frothy mass; the pressure being at the same time lowered, a new disengagement of gas occurs, accompanied by the formation of a second series of bubbles, mostly in the upper part of the ingot.

The contracted spaces at the summits of the first rank of bubbles serve as points of attachment for the second series.

This circumstance explains the well-defined limit between the zones of bubbles shown in Fig. 4 A, where the line *ab* indicates the limit between the liquid and solid metal at the moment of the fall of pressure, that is to say, at the moment the outer crust is ruptured.

Independently of the circumstances

which we have analyzed, a disengagement of gas takes place under the solid crust, and ceases only with the moment of the solidifying of the last molecules at the center of the ingot. The cause of this disengagement of gas lies in the constant diminution of elasticity of the gas accumulated under the hardened crust, partly by reason of the cooling, and partly owing to the enlargement of the funnel of contraction. It is easy to comprehend how, as a result of the above conditions, the interior of a steel ingot should contain an enormous number of rounded cavities.

The interior surface of these bubbles is of a pure silver white tint, but as the exterior bubbles commence nearly at the surface of the ingot, and as their cavities are separated from the atmosphere by a very thin wall only, it happens that the oxygen of the air penetrates this wall during the solidification of the ingot, so that these inner surfaces are more or less oxidized according to the greater or less facility of communication with the outer air. The sides of the funnel of contraction are for the most part oxidized by reason of the rupture of the outer crust before the hardening is quite complete.

We will now consider how the solidification of the ingot proceeds from the outside towards the center.

In observing the sides of a cavity of contraction, it is seen that they are covered with groups of entangled needle-shaped crystals. An aggregation of such crystals in the funnel of contraction forms a porous looking mass in which may be seen here and there cavities of considerable size. Figure 6 represents the lower part of such a funnel, and Fig. 7 a group of crystals taken from the friable sides of the central contraction of an ingot of 27 tons weight (having a diameter of 1^m 230, at a depth equal to one-fourth of the height of the ingot). The group is represented four times the natural size.

Fig. 6.

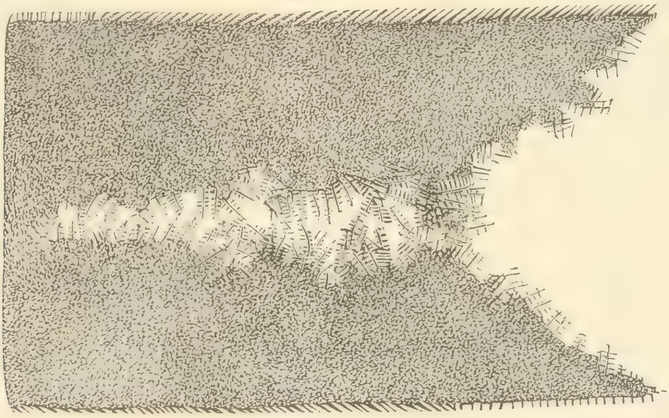


Fig. 7.

In observing these groups separately under the microscope, we notice that they have developed in directions following the axis of an octahedron, and that one of these axes, which is longer than either of the others, corresponds to the greater length of the crystal, so that each group forms a sort of skeleton crystal. Besides these axes of the first order, we find as we proceed from the summit of the crystal, axes of the second and third orders; at first only partly formed, and then more and more developed, until they form a kind of lattice

frame work following the lines of the octahedron.

Such a crystal is represented in Fig. 8. The dimensions of steel crystals, such as I have in my collection or have elsewhere seen, taken singly, rarely measure 5 millimeters in length. Generally they do not exceed 3 millimeters in length, and 1 to $1\frac{1}{2}$ in thickness. It is difficult to state their minimum size, as I have seen well-developed crystals that required a magnifying power of 100 to 150 to make their shape visible.

Generally, the crystals in growing do not develop in parallel directions, but cross at different angles, as we see in Fig. 7; but occasionally they group into a hemihedral form, as shown in Fig. 9, which represents a crystal magnified about 70 times, taken from a cavity of contraction in an ingot of 250 kilograms. Fig. 11 represents the outline of a crystal of the group shown in Fig. 7, magnified about 25 times.

Fig. 8.

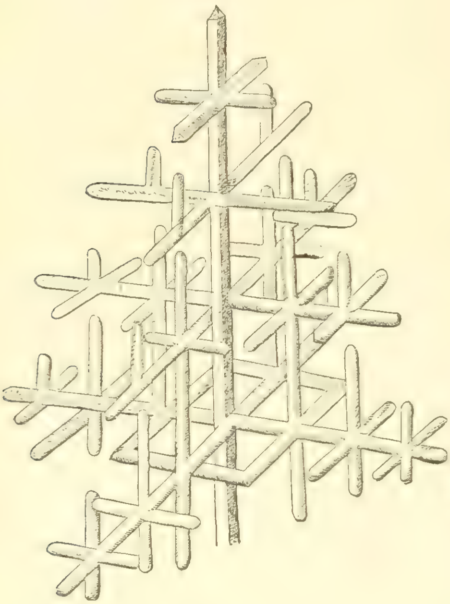


Fig. 9.

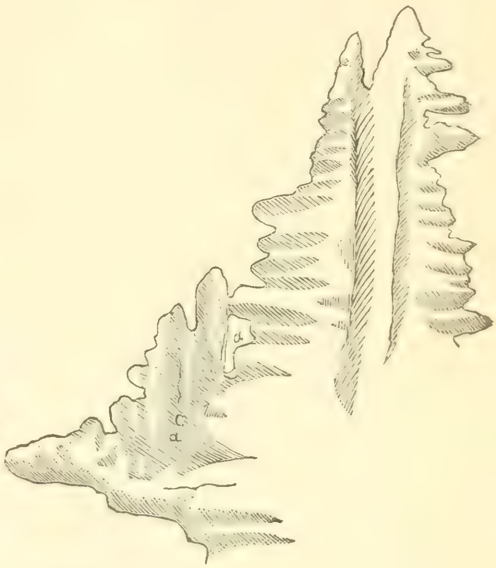
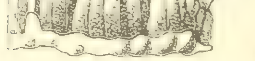


Fig. 10.



As the sides of all the cavities, and the porous part which surrounds the central cavity, are formed of crystals more or less developed, we are justified in concluding that the solidification of the steel does not consist in the constant thickening of parallel layers, but by a continuous formation of crystals, commencing with the cooling at the exterior and extending to the center of the ingot. The principal axes of growth should be normal to the sides of the mould, as in Fig. 17. The radial structure of the outer layer of the ingot also demonstrates this fact when the steel is poured into a metallic mould so hot that but few, if any, exterior bubbles, are formed. (See Fig. 19.)

If the diameter of the ingot does not exceed 2 or 3 inches, the radiations extend to the center of the ingot (Fig. 12), and if it be of square section, the diagonals become well marked by the meeting of the lines of crystals, which are developed at right angles to the sides. The planes of these diagonals are "planes of weakness," and are well

marked in chilled iron castings (Fig. 13). It is necessary to add that in the cavities of foundry pig iron we find crystals which strongly resemble those we have been describing. It is therefore probable that the solidification of steel and of cast iron follow the same law. Fig. 14 represents a crystal from a cavity in whitish pig iron, magnified 70 times.

Numerous observations upon the structure of the walls of cavities show that the higher the steel, that is the more carbon it contains, the better are the crystals developed.

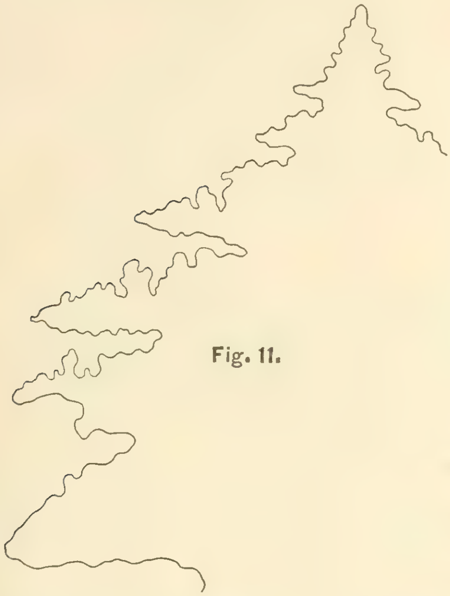


Fig. 11.

Fig. 14.

In mild steels containing less than 0.20 per cent. of carbon we find the crystals with difficulty, and they are always of very small dimensions. There exists probably a direct relation between the capacity of the crystal to develop and the property of the metal, which permits it to pass rapidly from the liquid to the solid state without passing through a pasty condition, which interferes with the rapid and regular crystalline growth. It is noticed in cast iron that the white varieties which cool rapidly acquire a radiated structure, which indicates a rapid formation of crystals; while in the gray kinds, in

Fig. 12.

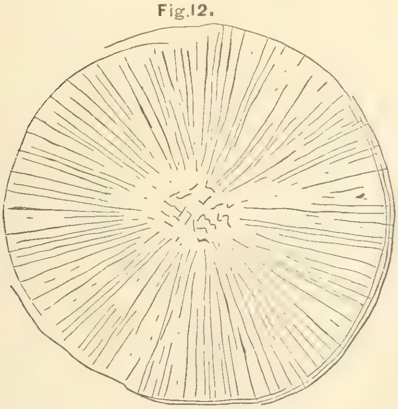
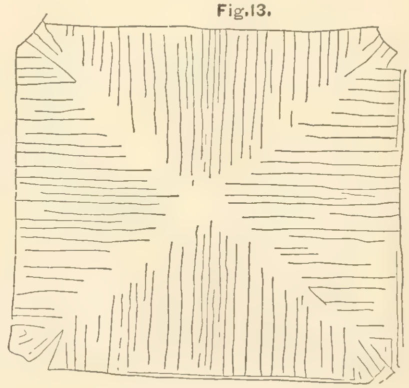


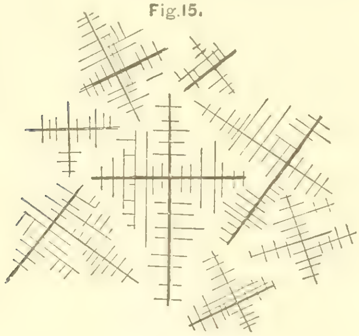
Fig. 13.



which the disengagement of carbon prevents the regular progress of crystallization, and which, in solidifying, pass through a pasty condition, exhibit a granular condition. The metal in crystallizing, while releasing the graphite, contains very little carbon chemically combined, although it probably retains the other constituents of cast iron.

In regard to the entangling of the crystals which form groups in the cavities of contraction, and in general in the central portions of the ingot, it is necessary to remember that the solidification of the steel in the central portions of the ingot is caused by the slow transmission of heat through the sides of the ingot which are yet red hot, although hardened. It therefore happens that crystallization begins simultaneously and grows from a great number of centers, and proceeds in many directions. Furthermore, the central part of the ingot while solidifying, is in constant

Fig.15.



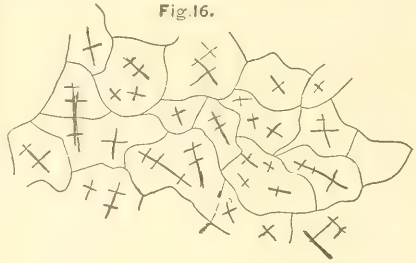
motion by reason of the sinking of the mass; this movement, although slow, is nevertheless quite sufficient to disturb the regularity of the growth of the crystals.

The chemical composition of these crystals, according to the analyses made at the laboratory at Obuchow, presents no regularity. They are always of the same composition, as the mass of ingot, whether it be high or low steel, so that there is no reason to suppose there is a definite combination of iron and carbon to form the crystal.

The crystals found in the hollows, formed in casting the ingot, have the same composition as the metal adjoining, but as the latter is harder than the mass of the ingot, it results that these crystals differ in being finer than those found in other parts, although having the same composition.

In describing the form of the crystals it was remarked that their growth was not perfectly regular; sometimes one

Fig.16.



side growing faster than the other; the axes of the second order developing faster than those of the first, they rob these latter of material—the axes meet and enclose between them a space filled with liquid steel.

In Fig. 9 the spaces $\overline{aa}$ are comprised between the axes of the first and second order; so that these spaces present themselves for separate crystals. The liquid metal of the enclosed spaces furnishes material for the growing crystals, but as the crystallization is attended by contraction, it happens that

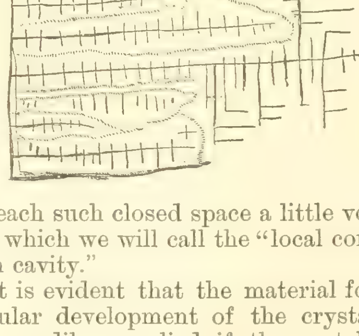


Fig.17.

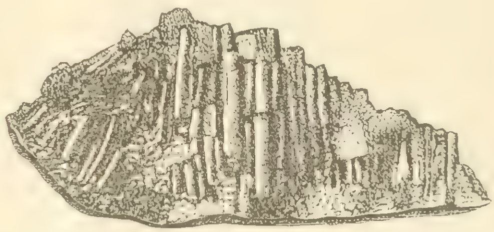
in each such closed space a little void is left which we will call the "local contraction cavity."

It is evident that the material for the regular development of the crystals is not readily supplied if the metal surrounding loses its mobility, a condition which is brought about during the hardening in the exterior portions of the ingot.

We may now see why the metal is found to be more and more porous as we approach the center of the ingot. The friability of the central portion is nothing more than the accumulation of local contraction cavities. On the other hand, the more compact the crystals, and the more rapid their growth, the more difficult does it become to supply material for their growth, even when the metal surrounding them is quite liquid. In circumstances similar to this must be the exterior portion of an ingot cast in a metallic mould, which rapidly absorbs the heat of the liquid metal; and this serves to explain the formation of the prismatic layer of the ingot, and the feeble cohesion of the prisms (Fig. 10). The local contraction spaces distribute themselves in such case between the planes of contact of the prismatic crystals, augmenting naturally near the cooling surface. The prisms have generally an irregular cross section, first, because the lateral axes of neighboring crystals have between them no definite relation; secondly, the distances between the principal axes are not equal, therefore some of the crystals growing near each other produce hemihedral forms, while crystals further apart develop independently; thirdly, as was remarked above, the growth of single crystals is frequently not symmetrical with reference to the principal axes.

Fig. 18.

Fig. 19.



In illustration of the preceding remarks is presented the transverse section of crystals, as shown in Fig. 15. When the growth is complete the cross section of contiguous prisms is represented in Fig. 16, a condition which may be recognized in the fracture of steel ingots of prismatic structure. Finally, Fig. 17 exhibits the growth of crystals normal to the surface of the ingot.

UTILIZATION AND PROPERTIES OF BLAST FURNACE SLAG.

By CHARLES WOOD.

From the "Journal of the Society of Arts."

The disposal of the enormous out-put of slag or scoria from blast furnaces has always been one of the serious difficulties of the iron trade. Taking an average of all the districts in England, for each ton of iron made, 25 cwt. of slag is produced, and from the official returns of last year of the iron smelted, no less than 8,000,000 tons of slag were produced. The space occupied by this mass, when loosely tipped, is something like 170,000,000 of cubic feet, or nearly twice the size of the Great Pyramid, whilst the bulk of the iron occupies only one-sixth of the same space.

There is, however, this great difference between iron and its refuse, that, whilst the former is diffused and finds its way into every corner of the world—from the hook at the end of the fisherman's line, or the hair-spring of a watch—from the magnificent steamship, or the abundant works upon the various railways, to the splendid roof of many of our public buildings, or the small but infinitely long rod of the telegraph wire—whilst

iron has been diffused through all these beautiful branches of the arts and sciences, its companion slag has been left behind at the smelting works, a hideous memorial defacing the landscape, absorbing something like a quarter of a million sterling annually in its disposal, and destroying forever hundreds of acres of valuable agricultural land, forming, as it were, a blot upon the face of the earth; and left as a landmark to show where this wonderful metal, iron, has been extracted, the development of which has contributed so much to bring the world to its present state of civilization.

That this state of things will entirely cease, the author does not, for one moment, think possible. So long as we produce such enormous quantities of iron, so long will these heaps go on accumulating. And there is little chance that these existing masses will ever be turned into a marketable product. At the same time, there can be little doubt that blast furnace slag possesses many valuable properties, which may, in certain localities, be converted into things useful to the arts and sciences, and—which is a most important point—at considerable profit.

There are other slags produced in many metallurgical operations—such as in the smelting of copper, lead, zinc, and tin ores—of which no use is made; but there are also slags, or cinders, produced in the manufacture of wrought iron, some of which are re-smelted, after which no great bulk of refuse is left. Nor is there, in the author's knowledge, any use whatever made of this residue.

Blast furnace slag, as it flows from the furnace when making foundry iron, is usually of a gray color, of much the same consistency as molten glass, a substance, in many points, it greatly resembles, particularly when the more siliceous ores are being smelted. It is very fluid, and has a temperature considerably above the melting point of cast iron; in proof of which, if a piece of cold cast iron be placed in a block, or wagon of fresh molten slag, it readily melts. At this high temperature, it contains a large quantity of gas, a considerable portion of which is thrown off or exuded as the slag cools down or becomes set. So much is this the case, that a large block or ball, technically so termed, will often burst, an hour or two after being run, from the accumulation of this gas in the inside. The bursting of these balls at the ironworks is of constant occurrence, and a source of danger, caused by the liquid slag and the outside shell dropping after the ball has burst. This is partially overcome by making the workmen knock a hole through the top crust before leaving the furnaces. Again, the least derangement in working of the furnace is quite sufficient to alter the nature of the slag, and often, within half an hour, will the slag be changed from grey to a perfect black. Such a color usually indicates imperfect smelting, and the slag will be found to contain a larger proportion of iron than it should do. Such, then, is the material with which blast furnace managers have to contend, and which forms their *bête noire.*

For many years the only known use for blast furnace slag was for road-making, and for this purpose it is still largely employed. In Northamptonshire, and in certain districts of Yorkshire, the whole of the slag produced is sold at a considerable profit. These, however, are local exceptions. Perhaps the largest user of slag is Mr. John Fowler, M.Inst.C.E., engineer for the Tees Conservancy Commissioners, whose works upon the breakwater at the Tees mouth deserve to rank as some of the most interesting in the kingdom. On these constructions Mr. Fowler consumes something like half a million of tons annually. A similar class of work is also being carried on at Barrow-in-Furness, from the slag produced at the hematite furnaces in that town; but, in consequence of the large amount of lime contained in this slag, much greater care has to be taken in its selection. The slag used at the Tees Breakwater is chiefly taken away upon bogies, in blocks weighing three and a half tons each. The slag is run into these blocks, upon the wagons, at the furnaces; a case or box being placed upon the bogie for this purpose. When the slag is sufficiently "set" this case is removed, and the wagon, with the block upon it, is taken a distance of about six miles to the breakwater. A large quantity is also tipped upon a platform on the river side, in such a position that the tide

completely covers it; it is then wheeled into hopper barges, belonging to and for the use of the River Tees Commissioners.

In consequence of the Tees Breakwater (known as the South Gare Breakwater) being now nearly completed, and the Tees Commissioners wishing to commence the breakwater on the opposite side of the river, called the "North Gare Breakwater," Mr. Fowler, in conjunction with the author, devised a plan for shipping the bogies with the hot balls into barges, and towing them down the river to a landing-stage constructed for discharging. Each barge is constructed to carry forty bogies, and will be about 220 tons burden. These barges will bring back the empty bogies on the return journey.

The loading of these barges at all states of the tide has naturally occupied a considerable amount of attention, and the machinery for shipment, designed by Messrs. Appleby Bros., of Southwark, and called a "Titan," has been recommended by Mr. Fowler, and generally adopted. Cantilevers, from a frame traveling on rails on the quay, overhang sufficiently to reach the outside of the slag barge, and a kind of overhead traveler runs backward and forward on these cantilevers, a distance of about 35 feet. The slag bogies are lifted and lowered by two steam-winches on the traveler, the centers of which correspond with the two lines of the rails upon the quay and upon the barge. A square shaft, running the whole length of the Titan, transmits all motions to the winches for lifting and traveling. Each winch has two drums for flat steel-wire rope, and these ropes are connected together by cross-beams, with slings for taking hold of each end of the bogies, the object being to pevent them from twisting when being lifted or lowered, and to ensure their coming directly upon the lines respectively on shore and in the barge.

The Titan is fitted with two lines of rails, one for full and the other for empty bogies. As already indicated, these lines correspond with those on the barge.

The mode of working is as follows:—When a barge-load of empty bogies are brought alongside, the bogies on the first transverse line are landed, and the barge is warped forward until the line which has been cleared comes opposite to the line for the loaded bogies; the traveling winch then picks up a loaded bogie, traverses out with it, deposits it in the barge, at the same time picks up an emptie bogie from the barge, then returns to the wharf, deposits it on the line for empties, and so on at each operation; so that the traveler takes out a loaded bogie, deposits it on the barge, and brings back an empty bogie each journey. The speeds of working are estimated to be equal to loading and discharging at the rate of 40 bogies per hour.

The engine, boiler, coal bunk, feed water tank, and counterweight box are fixed at the inshore end, and a platform on the traveler is provided for the driver, so that he stands directly above his work, and can clearly see each operation. One lever gives the motion of lifting and lowering, and another lever those for traveling in either direction. The whole of the work is performed by two men on the Titan, a stoker and traveler man, two men being required below to attend to the slings.

The next stage in slag utilization is the endeavor which has at various times been made of running the liquid slag, as it flows in a stream from the furnace, into moulds; or, in other words, making slag castings. Such an idea, at first sight, would seem natural enough. Here, it may be said, is a material flowing to waste, in a liquid state, capable of being run into moulds, and of taking impressions almost equal to that of cast-iron. The castings also, when successfully made, are exceedingly durable, and even beautiful to look at. So alluring has been the idea of casting, that, during the last fifty years, the Patent office has recorded, almost annually, the attempts of some inventor impressed with the notion that he could treat this treacherous fluid successfully, or, in some way or other, make it useful in the arts. To attempt to describe these various schemes, or to give even an outline of them, would occupy far too much time, but the author thinks that the following remarks will give a general idea of the difficulties he has had to meet.

The high temperature at which the slag leaves the furnace has been before noticed—namely, about 3,000° Fahr.—but, when it is brought into contact with anything cold, in the shape of a mould,

it readily parts with its heat, and, in so doing, suddenly contracts. The surface contracting becomes filled with fine cracks, or flaws; so much is this the case that, if allowed to become entirely consolidated in the moulds, these cracks will be found to penetrate completely through the casting, and, upon exposure to the air, the casting falls to pieces. This is the more vexing, as, when slag is run into a large mass—say into a pit of sand eight or ten feet deep, and containing from 30 to 40 tons—there is such an enormous amount of heat accumulated that it becomes self-annealing, the outside of the mass is kept at a high temperature, and, if allowed to remain until cool, not a flaw will be found, and the slag becomes so exceedingly tough and hard that it may be quarried in the same way as granite or Whinstone, and used for street paving.

There is, however, one exception to the numerous failures in slag casting, it is known as Woodward's patent, and although there is absolutely nothing new in the process, still, through the perseverence of Mr. Dobbs, the late manager and engineer for the furnaces of Messrs. T. Vaughan & Co., an amount of success has been arrived at sufficient to enable the company which works the process to pay a fair dividend. The success has been eminently a practical one, and appears to rest mainly upon two points—Firstly, in the quickness with which the castings are removed from the moulds and placed in the annealing ovens, where the temperature is constantly kept up nearly as high as the melting point of slag, the heat, after the ovens are full, being so gradually lowered that the outside of the casting cools at the same rate as the inside; the contraction is thus equalized throughout, strains upon the outside are avoided, and the fine surface cracks do not penetrate much below the skin. And secondly, upon the fact that only solid rectangular blocks, with a certain amount of bulk in them, are attempted.

On this wall is a diagram showing the apparatus and annealing ovens now in use at the works of the Tees Scoria Paving Block Company. The blocks are made by running the liquid slag into a series of open-topped moulds. The moulds are of cast iron, and are held by one end upon the periphery of a horizontal wheel or table. The wheel is suspended by tie-rods upon a central pillar. The moulds, when being filled up, are brought in succession under the slag-runner by the man in attendance, who watches until the mould is full. When the slag has become consolidated in the moulds a catch-hook is knocked up, the mould falls to pieces, and the brick drops to the ground. When they come out of these moulds, although consolidated, they are still in a sort of half-molten state, and are immediately removed into annealing ovens, which are always kept at a high temperature, so that the block receives no chill—the ovens are of small size, and, when full, are sealed up and allowed to cool down by themselves. There are about 70 moulds upon each machine, and the hotter these are kept the better; whilst, to prevent chilling of the molten slag, as it runs into the moulds, they receive a thick coating or washing of chalk or lime after each casting, the lime acting as a non-conductor as well as assisting the block more readily to drop out of the mould.

Thus it will be noticed that the casting is not allowed to remain in contact with anything which can extract its initial heat, so as to produce unequal cooling; and, as before stated, the whole success has been eminently a practical one, and reflects great credit upon those who have so patiently worked it out.

Large quantities of these bricks or paving blocks are used in the North of England for crossings, stables, yards, and streets; their durability, uniformity, and general appearance when well set is very pleasing. From a series of tests recently made, against a crushing strain, some of these blocks carried a weight equal to the hardest granite.

The next successful process for dealing with molten slag is that of Mr. Bashley Brittain's, who converts it, by a kind of compound process, into glass for bottle-making, and for many purposes where a pure white glass is not essential.

Sir Samuel Canning, Managing Director of Brittain's Glass Company, has kindly supplied the author with the following chief points of interest:

The slag is taken from the blast furnace in large ladles upon wheels, in quantities of about 500 lbs. In this state

it can be conveyed a considerable distance to the glass-works, where it is poured into a Siemens regenerative gas-furnace, known as the "continuous melting tank furnace." Through the kindness of Messrs. Howson and Wilson, of Middlesborough, the author is enabled to give a drawing of one of these furnaces, showing all the latest improvements. It has been designed by Mr. P. E. Eliott, late of Messrs. Chance Brothers, of Birmingham, the well-known glass-makers. It is arranged to work with gas made by a Wilson's gas producer, and is considered to be a great improvement upon the furnace employed at the slag glass-works at Finedon.

The material is fused and amalgamatal, in a melting tank. The fluid meted becoming fused, flows through a bridge, into a secondary chamber, called the gathering basin. The glass is withdrawn from this basin through a series of holes by the workmen, and fashioned into bottles, or other useful articles, in the usual way. By this arrangement, the work of charging and withdrawing the liquid glass is continuous, and proceeds uninterruptedly from Monday morning till Saturday night.

Messrs. Howson and Wilson assure the author that, with one of their gas producers, the consumption of coal per ton of slag glass should not exceed 10 to 12 cwts. With each charge of molten slag into the melting tank, alkalies and sand, and coloring or decolorizing material, are added in proportion, depending on the quality and color of, and the composition of, the glass required.

So far, the only slag operated upon is that produced from the Finedon furnaces in Northamptonshire, a very siliceous slag, the analysis of which is as follows:—

Silica	38.00
Alumina	14.87
Protoxide of iron	0.36
Protoxide of manganese	0.39
Lime	38.19
Magnesia	1.90
Titanic acid	1.00
Potash	1.58
Calcium. 1.55 } as Calcium Sulphur. 1.24 } Sulphide	2.79
	99.03

To make bottle glass equal in quality and appearance to French champagne and claret glass, about 50 per cent. of slag may be used; for plate glass, the same proportion, or rather less of slag; but, for glass for heavier articles, a much larger per centage can be adopted. Bottles made from slag glass are stronger than those manufactured in the ordinary way from the usual materials, and will stand from 320 to 350 lbs. per square inch, half bottles (pints) from 420 to 450 lbs. per square inch. Slag glass, owing to its toughness, is especially suitable for manufacturing into tiles, cisterns, plates, pipes, slates, &c., for which glass is not now employed. The chief points of merit claimed for the process are the utilization of a waste product, the economizing the heat of the molten slag, and converting it, with additional materials, into good glass, quicker, and at less cost, than by the processes generally employed.

The author has now revised the various processes where the slag is used in its crude cold state, or where the molten slag is either run into castings, or dealt with as in Mr. Brittain's process, and will now proceed to describe the inventions and manufactures with which his name is associated.

In 1871, the waste land for the deposit of the slag at the Tees Iron Works being filled up, and the works of the Tees Conservancy having been temporarily brought to a stand-still, it became of serious moment to know what was to be done with the slag.

The cost of cooling the slag, and putting it on board barges for taking it out and tipping it into the sea, was so heavy, that it was suggested that the slag should be prepared in such a form that it could be tipped into the barges, in the same way as coal is done upon the Tyne and other places. To meet these requirements, several schemes were proposed and tried; amongst the first (and only successful one) is the horizontal rotary slag-cooling table, designed and patented by the author, and which, with little alteration, continues to work up to the present time.

The machine upon which the slag falls revolves very slowly, and is about 16 feet in diameter. The top of this table is formed by a series of slabs; these receiving or cooling plates, or slabs, are about two feet in width, each forming a segment of the circle. These plates are

kept cool by having a zig-zag wrought-iron pipe cast in them, through which water circulates, being fed from a center globe; the water, after passing through two plates, flows into the basin under the table. These water plates are bolted down in such a way as to be able freely to expand and contract. The liquid slag, as it flows from the usual runner, spreads itself upon the moving table into a broad band of slag, varying in thickness from half an inch to three quarters, depending upon the quantity and fluidity of the slag. From the point where the table receives the molten slag, a distance is traversed of about 10 or 12 feet, to allow the slag to consolidate; after which water from a jet is made to flow freely upon the surface of the hot slag until it reaches a set of scrapers, when, having become nearly cool, it is pushed off into iron wagons below.

When the slag reaches the scrapers, it has become somewhat brittle, and readily parts from the table and slides off in large flat pieces. When perfectly cold, it is tipped from the wagon, and falls into small-sized pieces, samples of which are shown. This material was christened by Mr. Fowler, the Tees Commissioners' Engineer, "slag shingle," by which name it is now commonly known.

The produce of this machine has found such ready sale that it has been kept going almost constantly ever since it started, and about 200,000 tons have been sold, chiefly for making concrete. In place of paying 6d. per ton to get rid of it, it has realized about 1s. 3d. per ton.

The large concrete blocks, each weighing about 230 tons, constructed by Mr. Fowler, for dropping into the sea, to form the head of the Tees breakwater, are chiefly composed of this material, and several heavy foundations for engines, drainage work, building, &c., in the district, have been executed with it.

The next great step in advance, and which has laid the foundation for the several processes hereinafter mentioned, was the reduction of the molten slag, as it flows from the furnace, into a soft spongy kind of sand, by a machine known as Wood's slag-sand machine. In principle it is the reverse of the slag-shingle machine, inasmuch as, instead of the wheel being horizontal, and the slag running upon a dry table, the slag flows into a wheel placed upon its edge, and falls into a bath of water, varying in depth from 18 to 24 inches. The wheel, or drum, is of wrought iron, and about 14 feet in diameter. It is fixed and carried on curved arms. The arms are curved, to allow, in the first place, the slag runner or spout, to enter the wheel; and, secondly, to make room for the sand-receiving spout on the opposite side at the top. The wheel makes about five revolutions per minute, and the water contained inside is partly carried up by the elevators and, in falling, causes a constant rush of water to the bottom. Perforated screens, or elevators, are arranged to screen the slag from the water, and lift it to the top of the machine, where it drops upon the sand-receiving spout, and thence slides in a constant stream into wooden wagons. The spout is also perforated, to allow any water which has been carried over with the sand to return again into the machine. The perforated buckets have another important function to perform, viz., that of agitating the water. The water, in rushing to the bottom, meeting these obstructions, rolls over in a violent manner, and into this agitated water the liquid slag flows just as it comes from the furnace. The united action of the agitated water and the formation of steam scatters, as it were, the molten slag in the water into the material called slag-sand, some of which is exhibited; as also a working model of the machine. The wear and tear of this machine is very light, there being no working parts coming in contact with the sand or the heat. The heat, being taken up by the water, is thrown off in the shape of steam, which comes away in large volumes. Grey slag takes up about 20 per cent. of its own weight in water. The total cost of this sand in railway trucks is about 6d. per ton. At the Tees Iron Works the author has three of these machines and two single machines generally at work.

On the Continent a kind of slag sand has been made—prior to the adoption of the process just mentioned—by running the slag into tanks full of water, and elevating the sand by chain buckets into wagons; but the apparatus is very imperfect, and will only work slag made

from forge iron, known as black slag. The application of slag-sand, in so cheap a form, to the useful arts naturally followed the production, and, after numerous experiments, extending over many months, it was decided to establish separate works in close proximity to the furnaces, where, under the author's own directions, various processes could be developed; and, in 1876, the first manufactory of the kind was started. Although in Georgemarienhutte, in Hanover, under the direction of Herr Luurnan, a process of brickmaking was started a few months previously.

The remarkable setting properties of slag in a state of subdivision has attracted the attention of scientific men for many years, and many schemes for producing artificial stone, cement, &c., have been tried; but, in consequence chiefly of the cost of disintegration, no results were obtained with commercial success.

Mr. John Gjers, of Middlesborough, about fifteen years since, produced a coarse kind of slag-sand, which, after grinding under edge-runners, was used extensively for some little time upon the pig beds; but it had to be abandoned, because it consolidated too much, causing violent explosions (technically termed "boils"), from the steam from the damp sand being unable to escape when the metal was run from the furnace in pigs.

Thus, it will be observed that, up to the time when the Cleveland Slag Works was started, there was not a single instance of slag utilization in this country—otherwise than for road-making, or for river work—commercially carried on. Before proceeding to describe the various manufactures produced at the Cleveland Slag Works, at Middlesborough, it is necessary to draw your attention to the chemical nature of the material operated upon. The following analysis gives a good general idea of the chief slags produced in the United Kingdom:

	Cleveland.	Hematite Bessemer.	Dowlais.	Dudley.
Lime	32.68	50.55	30.47	35.68
Silica	36.50	30.50	43.07	38.76
Alumina	22.95	15.00	14.85	14.48
Protoxide of iron	0.06	0.45	2.53	1.18
Protoxide of manganese	0.32	0.10	1.37	0.23
Magnesia	5.83	2.00	5.87	6.84
Potash	0.59	0.40	1.84	1.11
Soda	0.37	0.20	..	..
Sulphur	1.73	1.50	0.89	0.98
Phosphoric acid				
	100.90	100.70	100.89	99.26
Less oxygen of the lime combined with sulphur.	0.86	0.75	0.44	..
	100.04	99.95	100.45	..

A table of comparative analysis is given below, for easy reference. It will be noticed that three most

	Slag.				Portland Cement.	Slag Concrete Bricks.	Slag Cement.	Gypsum.	Puzzalanas.
	Hematite Bessemer.	Cleveland.	Dowlais.	Dudley.					
Lime	50.55	32.68	30.47	35.68	60.88	29.90	22.90	32.32	8.00
Silica	30.50	36.50	43.07	38.76	23.16	25.15	21.60	0.35	..
Alumina	15.00	22.95	14.85	14.48	7.68	21.80	19.85	..	..
Protoxide of Iron	0.45	0.06	2.53	1.18	..	1.44	4.00	..	..
Protoxide of Manganese	0.10	0.31	1.37	0.23	..	0.26	0.21	..	..
Peroxide of Iron	..	..	..	..	3.00	1.66	8 80	..	12 to 15
Magnesia	2.00	5.83	5.87	6.84	1 01	5.10	4.36	..	..
Potash	0.40	0.59	1.84	1.11	0.72	0.53	0.50	..	..
Soda	0.20	0.37	..	..	0.31	0.36	0.32	..	..
Sulphur	1.50	1.73	0.89	0.98	0.05	1.00	1.19	..	..
Sulphuric Acid	..	..	..	..	2.60	1.25	1.54	46.18	..
Phosphoric Acid	..	..	..	..	0.08	0.01	0.02	..	..
Carbonic Acid	..	..	..	..	..	2.60	3.00	..	..
Water (of crystalization)	..	..	..	..	0.77	9.50	12.00	21.00	..

important component parts of these slags are silica, alumina, and lime, forming, as they do, about 90 per cent. of the whole. The two latter of these, however, chiefly exist as silicates; if, to these caustic lime be added, the silicates are acted upon. Water of combination, or crystallization, is taken up; and, if the material be kept damp and exposed to the air, hardening or induration is carried on for months.

If caustic lime be added to slags poor in lime, so as to bring this element up to 55 or 60 per cent., it will be seen at once how closely it will resemble the analysis of Portland cement, the composition of which is as follows:—Lime, 60 per cent.: silica, 24 per cent.; alumina, 8 per cent.; oxide of iron, 4 per cent.

German Portland cement is sometimes made with as low as 55 per cent. of lime, whilst Roman cement has often only 50 per cent. of lime; but these will generally be found to contain oxides of iron in an increased proportion.

The remarkable hardening effect of oxides of iron in conjunction with lime, silica, and alumina, is well known, and is well exemplified in the Italian puzzolanas, where, in several of the best qualities, the lime is actually as low as eight per cent., whilst the oxides of iron run up to 12 or 15 per cent. The hardening effect of oxides of iron induced the author, prior to the development of the slag industries, to employ the dust from the ironstone clamps in place of sand, when making concrete for heavy foundations; and the setting properties and strength of this combination have upon examination been fully confirmed. Again, having to erect a row of columns for a large roof upon the bed of an old ironstone clamp, the floor of which had been accumulating for several years, it was found to be so extremely hard that the author simply levelled the bed down, and set the columns directly upon it. These, after many years, show not the slightest signs of settlement, although the ground underneath had been made up from ship's ballast.

It appears an absolute necessity for obtaining good results, that the ferruginous material should be calcined, or roasted, the effect of which is to drive off the carbonic acid and water; the reabsorption of the water, which unites in chemical combination with the material, afterwards assists in hardening.

These remarks would seem to be a digression from the question of slag utilization, but, as will be seen hereinafter, they bear directly upon the manufactures carried on at the Cleveland Slag Works.

The most important production, and the one which consumes by far the greatest quantity of slag, are concrete bricks, known in the market as slag-bricks. These bricks are made from the sand produced by the slag-sand machine before described. The sand is dropped from the railway wagons into hoppers, or depôts, at the works, from whence it is filled into large barrows, and is taken up a hoist to the top of the building, and tipped into a hopper, which supplies a measuring apparatus. Here it is mixed with a certain quantity of selenitic lime (General Scott's patent), with an addition of iron oxides; it then passes into the brick-press, hereinafter to be described. The bricks are taken off the presses by girls, placed upon spring-barrows carrying fifty bricks each, and removed to air-hardening sheds; here they remain a week or ten days, after which they are stacked in the air to further harden, and at the expiration of five or six weeks they are ready for the market. Specimens of these bricks are shown. We here have, then, the curious anomaly of bricks being made without burning, and of a wet season being favorable to the hardening process. The bricks thus produced are very tough; they do not split when a nail is driven into them, and are easily cut; they do not break in transit, and the frost has no effect upon them. According to a certificate received from Kirkaldy's testing works, some of these bricks, taken from stock three years old, carried a pressure of 21 tons before crushing, whilst others only four months old crushed with nine tons pressure, showing not only great toughness, but also that they greatly improve by age.

There are now two machines fully employed, making about 130,000 bricks weekly, consuming 250 tons of slag sand and 30 tons of selenitic lime and oxides.

The preparation of this selenitic lime forms a necessary branch of the business. It is made in the following manner:

80 per cent. of unslacked common lime.
10 per cent. of raw gypsum.
10 per cent. of iron oxides calcined.

These are all ground together, under edge runners, into a fine dry powder. The composition is then passed through a fine sieve, 24 meshes to the inch; it is then ready for the brick press. To each thousand of bricks, 6 cwt. of this lime is used; no water is added, sufficient being held in suspension in the slag sand to thoroughly moisten the lime; in fact, it is no uncommon thing to find a stream of water flowing from the brick press which has been squeezed out of the sand.

The loss of bricks in manufacture is very small; in fact, after the bricks are once upon the barrows, the waste is not more than 1½ per cent.

At the present rate of production there is a consumption of slag for this one article alone of about 14,000 tons per annum.

The weight of these bricks is about 30 per cent. lighter than ordinary red ones —9 in. by 4½ in by 2½ in.—weighing only 2¼ tons per thousand.

Another interesting feature in connection with these bricks is the economy in manufacture, which—including all materials, labor, wear and tear of machinery, &c., superintendence, power, and everything, except interest on capital, does not exceed more than 10s. 6d. per thousand.

The following is an analysis of these bricks, made by Messrs. Patterson and Stead, and will be found worthy of notice, showing the hardening properties contained, the composition comparing favorably with the cements previously mentioned:

	Per cent.
Lime	29.90
Silica	25.15
Alumina	21.80
Protoxide of iron	1.44
Protoxide of manganese	0.26
Peroxide of iron	1.66
Magnesia	5.10
Potash	0.53
Soda	0.36
Sulphur	1.00
Sulphuric acid	1.25
Phosphoric acid	0.01
Carbonic acid	2.60
Total water	9.50
	100.56
Less oxygen of the lime combined with sulphur	0.50
	100.06

As before-mentioned, the lime used for making bricks is selenitized, the following being the analysis of the raw gypsum employed in the process.

	Per cent.	
Sulphuric acid	46.18	Sulphate of lime.
Lime	32.32	
Silica	0.35	
Water at 100 per cent	Nil	
Ditto given off at red heat, being water of crystallization	21.00	
	99.85	

The process of brick-making, as now carried on, is extremely simple, and, as already shown, inexpensive; but it was here that the greatest difficulties were met with.

There was no machinery to be purchased that could work the slag sand into bricks, in the state in which it arrived from the blast furnaces. In the earlier attempts the sand had to be prepared in a fine state, the result being a superior class of bricks, but of a cost so great as to exclude them from the market. The author had, therefore, to design and construct brick presses and other machinery that could work the sand, as it came from the slag-sand machines, directly into bricks. The success of this machinery at once rescued the Cleveland Slag Company from an early collapse, but not before a large amount of money had been spent, and some two years wasted.

A description of this machinery is given further on; but, in designing the press, the following points had to be kept in view, viz.: unusual depth of brick moulds, as the sand (being spongy) is exceedingly compressible; great pressure, in order to consolidate the slag; as well as great care in mixing the lime in fixed proportions to the sand—too much lime tending to burst the bricks, whilst too little seriously affects the hardening.

The next product to be described is the manufacture of what is called slag cement. The word cement has sometimes been objected to in connection with this material, because it is generally manufactured in a wet state, and must be used within a few hours after being made. Upon this point the author expresses no opinion, simply mentioning

the fact that, in point of strength, he finds little difference whether the materials are ground together in a dry or in a wet state. The cost of production, however, is, as nearly as possible, four to one in favor of the wet state. It is made by grinding under edge runners, for about one hour (the finer the better), 70 per cent. of slag sand, 15 per cent. of common lime, and 15 per cent. of iron oxides, calcined iron stone, or spent pyrites.

The following is an analysis of this cement, lately made by Messrs. Patterson and Stead:—

	Per cent.
Lime	22.90
Silica	21.61
Alumina	19.85
Protoxide of iron	4.00
Protoxide of magnesia	0.21
Peroxide of iron	8.80
Magnesia	4.36
Potash	0.50
Soda	0.32
Sulphur	1.19
Sulphuric acid	1.54
Phosphoric acid	0.02
Carbonic acid	3.00
Total water	12 00
	100.29
Less oxygen of the lime combined with sulphur	0.59
	99.70

Upon comparing this analysis with that of Portland cement, and the puzzolanas already given, it will be seen that the various hardening ingredients exists in all.

The large quantity of water held in suspension in the slag sand is quite sufficient to make the mass in the mill into a semi-fluid state, but this water is mostly taken up in setting, as water of crystallization. It is, therefore, necessary that the cement should be used before setting takes place. This cement is usually employed for making concrete, by mixing one part of the cement to five parts of slag shingle. The shingle is made by the slag-shingle machine before described.

The shingle, before being used, is well wetted; and when the concrete is put into place, it is beaten lightly down in a soft state, until the water and cement begin to rise on the top; two days afterwards it has become sufficiently set to allow of the building boards being taken down, and at the end of a week it will be fairly hard, and will go on hardening for months. It is perfectly hydraulic, and will harden under water. It will be seen by this that it requires longer time to set than Portland cement, and is perhaps not quite so hard; but there is a remarkable toughness, which has surprised all those who have used it, and this toughness makes it valuable for heavy machinery foundations, &c.; and, when made in proximity to the furnaces, the cost of the cement will not exceed 6s. per ton, whilst concrete made of this cement and slag shingle will cost only 5s. 6d. per cubic yard.

These prices are absolute figures of cost, that of the concrete being arrived at after having executed many hundreds of cubic yards, both upon the Tees Iron Works, at the new railway station at Middlesbrough, and elsewhere. The Slag Works' buildings, the walls of which are between 70 and 80 feet high, are built entirely with it, the basement walls being 2½ feet thick.

Whilst the underground walls of the Slag Works were being executed, they were twice immersed, through exceedingly high tides, with the result that this part of the building is the hardest of all; and to give an idea of the strength, the author may mention that it was necessary, about eighteen months ago, to cut two openings at different points through the basement walls, 3½ feet wide and 6 feet high. This employed two good workmen, with steel bars and sledge hammers, at least four days for each doorway.

The author knows of no material at a similar cost which can compete with it, and he is satisfied that it has only to be widely known to be more extensively used. Personally, where time can be given, he employs nothing else for all heavy foundations for rolling machinery, for which purposes, a conglomerate or monolithic mass, it is peculiarly adapted. Slags from the furnaces making Bessemer iron are better adapted to this cement even than those from the Cleveland ores.

Mention has been made of the necessity of keeping the products from slag sand in a damp state for a length of time after manufacture, in order to give them time to harden, or, in other words, to

allow the material to absorb or take up as much water as will chemically combine with the lime, silica and alumina; but whether this water becomes water of crystallization, or water of hydration, or a combination of both, is not at all certain. The author is, however, strongly, impressed with the idea that water in a fixed state, more particularly in a compound state, plays by far a more important part in the setting of cements than is generally supposed; that the presence of water in a chemically combined state forms as much a constituent part of cement as does the lime, silica, and alumina, seems certain from the results of the analysis shown further on. For instance, if Portland cement be heated to a red heat, so as to evaporate the fixed water, the cement loses at once its strength, and becomes rotten. Again, with gypsum, where the water of crystallization amounts to more than one-fifth of its bulk; if this is driven off at a red heat, we have little better than a powder left. And its seems clear that the quicker this crystallization takes place, the quicker is the setting; and on the contrary, as in the slag cements and the brick, the slower the water is in becoming fixed the slower is the hardening, thus showing the necessity of keeping them damp during the process.

At the author's request, Messrs. Patterson and Stead have made many analyses, with the object of testing this point. Samples of Portland and Roman cements were mixed with water in the usual way, some specimens being supplied by the cement manufacturers themselves, as test pieces from their works, and had consequently been under water for various periods. These were all reduced to powder, and carefully dried by keeping them for several hours at a temperature of 212° Fahr., so as to evaporate every particle of free mechanically mixed water. A very careful determination of the chemically combined water was then made, with the following interesting results:

Combined Water.

Four days in water.		Six days in water.	
Portland.	Roman.	Portland.	Roman.
5.75%	5.25%	6.8%	6.78%

Seven days in water.

Portland.	Slag cement.	Slag brick.
7.75%	10.50%	5.70%

From this it seems certain that the hardening follows closely in proportion to the quantity of water which becomes chemically combined, and that the slag cement undergoes a similar change to that which takes place in Portland or Roman cements. That other chemical changes take place there seems also to be no doubt, but what these changes are, the author leaves it to wiser heads than his own; he only wishes to show that with Portland, or Roman, or slag cement—time being left out of the question—the same chemical changes do take place.

Mortar for building purposes is also another material supplied at the Cleveland Slag Works. It is simply made by grinding the slag sand with about six per cent. of slaked lime in an ordinary mortar mill, and (if ground fine) makes a far better mortar than is generally employed by builders. Two years ago there was a very large demand for this material in Middlesborough, but the building trade has so completely come to a standstill, that at the present time not much is being used. There is only one objection made to it, viz., that it sets too quickly. Mortar supplied on the Saturday, left unused, would be worthless on the Monday. As with the other slag products, its remarkable strength and cheapness combined makes it much liked by those who, in close proximity to the works, can obtain it freshly made.

One other manufacture from slag is carried on at the Cleveland Slag Works, which, although it does not consume much, is still of interest, viz., artificial stone. It is moulded into chimney pieces, window-heads and sills, balustrading, wall coping, and other ornamental work for builders, as well as for paving for footpaths, stables, &c. The stone is composed of two and a-half parts of finely pulverized slag, and two and a-half parts of ground fire-brick, to one part of Portland cement; the mixture is run into moulds, and sets quickly, the articles being ready for the market in five or six days.

In a works where so many special manufactures have been developed, the arrangement of the building—the design, position, and working of the machinery at present used—must necessarily have been arrived at only by hard-earned ex-

perience; and the author has thought that this paper would be incomplete without a description of the factory at Middlesborough, with such further modification as an experience of five years' working has suggested.

The building is constructed of slag-cement concrete throughout; the main building has four floors, the size of which are 46 feet by 33 feet, whilst the slag-sand stores, gantry, engine house, lime house, &c., occupies 97 feet by 47 feet. The slag sand is brought from the blast furnaces in large wooden railway trucks, holding between seven and eight tons each, and is run up an incline by the locomotive into a gantry. The bottom doors of the trucks are opened, and the slag sand is dropped or emptied into hoppers below. These hoppers are capable of holding about 600 tons of slag sand, or storage enough for one week for three machines, and should be kept constantly filled. From these hoppers it is drawn into large wheel barrows, and is taken up by a double-acting hoist to the top of the building.

This hoist is driven from the main shafting in the mill, and is worked by two belts, one crossed, the other open, for the purpose of reversing the cages. The cages can be made to stop themselves at any floor, and have a self-acting brake to prevent any movement of the cages after the straps are thrown off, the action being most simple and effectual.

The sand barrows are taken from the hoist at the top of the building, through a passage, and tipped into the hopper, which supplies the brick presses. Selenitic lime is fed into a small hopper, by hand, from a chamber or floor above. At the bottom of these sand and lime hoppers are the measuring apparatus, which accurately measure both the lime and the sand in the exact proportions necessary. From the measuring drums, the material falls upon sifting and mixing apparatus from which it falls through the floor into the brick press. This press has been designed especially for the purpose, and has many new points. It is of immense strength. The pressure is obtained by two cast-steel cams, which are fixed upon a forged steel shaft $7\frac{1}{4}$ inches in diameter; this shaft, resting on bearings between two strong frames, is put in motion by very powerful double-geared spur wheels, the first motion shaft having a heavy fly-wheel upon it to steady and equalize the pull upon the strap. The pressure cams act against rollers fixed upon two steel cylinders, or rams. These rams transmit the pressure to the moulds under the table. The table is circular, and contains six pairs of moulds, so that four bricks are pressed at one time, the table remaining stationary during the operation. At the same time the bricks are being pressed, two other pairs of moulds are being filled up with material, whilst the other two pairs are delivering up the four bricks already pressed at the previous revolution of the cam shaft. The bricks are pushed out of the mould by smaller pistons, which are acted upon by separate cams. The moulds are lined with changeable steel plates three-sixteenths of an inch thick, and the sand and lime is fed into two pug mills. These pug mills are fitted with six knives each, so as the more thoroughly to mix and chop the spongy slag with the lime. The table is shifted round by a kind of ratchet motion. Immediately above the pressure-cylinders are two pressure-stops, which are held down by the heavy-weighted levers. These levers therefore, receive the whole pressure put upon the bricks; and, in case there should be too much sand getting into the moulds, they simply lift up and relieve the strain. The weights can be weighted at option, and thus form an exact gauge of the pressure upon the bricks. The moulds are generally filled so as just to lift the levers in ordinary work. The filling is easily regulated by the set of the knives on the pug shafts, which press the material into the mould and one side of the pug-mill cylinder is made to open so that the knives are accessible at any moment.

The pug mills are filled by means of measuring and mixing apparatus placed on the floor immediately above the brick press. The mixing and measuring apparatus is very simple and efficient, and works without trouble. The slag sand is tipped into a hopper by large barrows, which are lifted up by a hoist. At the bottom of this hopper there is a revolving cylinder, with ribs cast upon it, which, revolving under the hopper, carries a certain thickness of sand, the thickness having been previously regu-

lated to the requirements of the press. The slag then falls upon a sieve, which separates any large pieces of slag in a solid state, and at the same time allows the falling sand through the sieve to fall like a shower. The lime is fed into a separate hopper, and is regulated by a feed-roller of smaller size. The lime then passes down a shoot, which forms part of the slag-sand sieve, where it meets the shower of sand—falling together with it—thus getting thoroughly mixed. On the right-hand side of the slag gantry and hoppers is the mill for preparing the selenitic lime. The lime, after being ground under edge runners, is passed through a sifting apparatus, the wire of which has 24 meshes to the inch; it then falls into a hopper, is taken by barrows through a passage to the hoist, and lifted to the lime chamber, before mentioned. In a line with this mill, and parallel with the slag gantry, are the stores for the lime, gypsum, and iron oxide, whilst behind the lime-house are the engine and boiler.

The hardening sheds are three in number, and should be each about 100 feet to 40 feet. The floor must be perfectly smooth and level—this being an important point—as an uneven floor spoils the bricks. The sheds should have plenty of ventilation, and require to be cool in summer. Great care is necessary in stacking these bricks, as they come off the barrows. They are placed on edge quite close together, and stacked six in height, and when once here in position, there is little or no loss afterwards.

A material containing so much lime, silica, alumina, sulphur, and magnesia, in a condition like the white soft slag sand, suggested its application as a fertilizer for some kinds of lands. Three years ago, through the kindness of Earl Cathcart, it was brought before the Royal Agricultural Society, and Dr. Voelcker reported "that the result of his examination shows that it may be usefully employed upon moorland and peaty soils as a cheap and effective substitute for lime."

Since this report was made, many hundreds of tons have been sold for this purpose, and although there was only 32 per cent. of lime in the slag supplied, the results have been very satisfactory, particularly on land growing potatoes. Had it been Bessemer slag, containing from 40 to 50 per cent. of lime, there cannot be a doubt but that the results would have been still more satisfactory, and the author feels sure that it must, in some localities, find a large outlet for this purpose.

Mr. Frederick Ransome, M.Inst.C.E., the well-known inventor of the artificial, siliceous stone, has recently taken out a patent for mixing the slag sand in its wet state with chalk, and then burning the whole together in a cement kiln into clinker, after which he grinds it down in the same way as Portland cement. The results given are most remarkable, exceeding Portland cement in strength by nearly 30 per cent. The experiments are of so recent date that the author has considered it better not to give any further statistics.

A sort of concrete brick has, during the last few years, been made at the Moss Bay Iron Company, Limited, Workington, from hematite Bessemer slag, under the direction of Messrs. Kirk Brothers, Mr. Henry Hobson being the then manager, and, I believe, the originator of the process. These bricks have been made by a process differing entirely from the system adopted by the author at Middlesborough, and already fully described. The slag employed at Moss Bay is pulverized from the cold solid slag, under massive edge runners, which crush the material into fine dusty shingle; it is then lifted by elevators into French burr stones, and ground down as fine as sand. From the stones it passes through a worm conveyor to a brick press, during which about 25 per cent. of common river sand is added, with sufficient water to thoroughly damp it, without any addition of lime, again showing, in a remarkable degree, the extraordinary setting nature of the slag, after the chemical combination with the water and exposure to the air has taken place. These bricks are taken from the press, and placed under cover for a few days, when they are put out in the open air to harden. The bricks are of excellent shape, grey color, and become exceedingly hard, as will be seen from the specimens exhibited. Large quantities of these bricks have been employed in building the Moss Bay Steel Works, and

appear to be standing remarkably well. The cost, however, is very heavy, owing to the difficulty of preparing the slag, and the wear and tear of the machinery; the excessive weight also precluding the sale at any great distance from the works.

The large amount of lime, combined with the silica and alumina in the Bessemer slag, as seen in the analysis already given, quite accounts for the setting properties. With the exception of the bricks used upon the works, the author believes that there has not been any large quantity made, and the machinery has now been standing many months. The process is, however, again another proof, in a very interesting way, of the peculiarities of the material. The bricks continue to harden for years, and appear to arrive at a kind of crystalline fracture, which damp greatly accelerates. There is no doubt whatever that if this slag were treated by the process adopted by the author, that bricks, in every way superior to the ones thus described, and, from the nature of the slag, superior, even as a building brick, to those produced at Middlesborough.

There remains, now, only one more application of blast furnace slag for the author to trouble you with. It is the manufacture of slag wool, or silicate cotton, so-called from its resemblance to cotton-wool. The first attempt at this manufacture was in 1840, by Mr. Edward Parry, in Wales, and a large quantity was made, but no effort appears to have been made to confine the wool after production, consequently it floated about the works with the slightest breeze, and became so injurious to the men that the process had to be abandoned.

About four years ago Herr Krupp, of Essen, and a little later, Herr Lurrman, of Georgmarienhutte, in Hanover, both supplied a great deal to the market, but the precise method of manufacture has never transpired, having been kept a secret at the works; and until two years ago it has never been successfully made in this country.

As carried out by the author at the Tees Iron Works, the process is exceedingly simple; a jet of steam is made to strike upon the stream of molten slag, as it flows from the usual spout into the slag wagons or bogies. The steam scatters the slag into shot. As each shot leaves the molten stream, it draws out a fine thread, just in the same way as when you touch treacle lightly with the finger; if you lift it up you will see a fine thread attached. The consistency of molten slag is not unlike treacle; each shot makes a fine thread which, losing its heat, becomes set like glass. The shot being heavy, drops to the ground, but the thread is sucked into a large tube by an induced current of air, caused by the steam jets, and the wool is discharged into a large chamber. The finer qualities float about and settle near the outside, whilst the heavier or larger fibres lie chiefly in the center of the chamber. After each blowing, the chamber presents a most remarkable and curious, as well as a beautiful appearance.

The wool, as will be seen by the specimens shown, is of snow-white color, and attaches itself to the sides and roof, or to anything which it can touch, in the same manner as a light fall of snow does in calm weather upon every tiny twig of a leafless tree. The wool is taken up daily with forks, and put into bags for sending away. It is principally used for covering boilers or steam-pipes, for which purpose it is peculiarly adapted, as being a splendid non-conductor of heat, and incombustible. About four tons of this wool is produced per week, and, as only one quarter of a cwt. is made from each ton of molten slag operated upon, you will see that the process is not a very rapid one.

In conclusion, the author hopes that the progress which has been made during the last few years towards the utilization of this hitherto neglected material may induce others to assist in converting it still further into what is useful to man, and in place of being an incumbrance and a nuisance, continually encroaching upon valuable land, it will more and more assume a condition of value.

French Railways.—The new railways now under contract will increase the French lines from 22,193 kilometers to 40,000 kilometers. Most of the work will be done under the superintendence of the government agencies, and the lines will be managed under state supervision, but not at government expense.

THE PRESERVATION OF IRON SURFACES.

From "The Engineer."

About two years ago two processes were described for the protection of iron surfaces from rust. The first referred to is that of Professor Barff, the second is that of Mr. George Bower, of St. Neots. The result sought to be attained by both inventors is the same, namely, the formation on the surface of the iron of a coating of magnetic oxide of iron, but the means adopted are different. At the time referred to Professor Barff had already attained considerable success, while Mr. Bower's process was still immature and undeveloped. During the two years which have since elapsed, Mr. Bower has worked hard and overcome a great many difficulties, and his process is now so far complete that he can produce the results he aims at with uniform success. We do not know what Professor Barff has recently effected, and we can only compare Mr. Bower's practice of to-day with that of Professor Barff's of two years ago; but it is certain that he has succeeded in doing that which Professor Barff could not do then, and the whole process is at once simpler, cheaper, and more manageable than that of the Professor.

The magnetic oxide of iron is a substance whose nature and mode of formation is not quite well understood. It is assumed by chemists to have the formula $Fe_3 O_4$, but some doubt has been entertained concerning its accuracy. In order to produce the oxide, it is essential that the oxidation of the iron shall take place at a high temperature, and that only a limited quantity of oxygen shall be present. The Barff process consists in placing the articles to be coated in an oven or furnace sealed up air-tight with clay. In this they are heated to a cherry red, a current of very highly heated steam is then turned into the oven; the superheated steam is at once decomposed; the iron seizes the oxygen, while the hydrogen is left free and discharged by a small pipe into the furnace. The quantity of oxygen can thus be minutely regulated by controlling the influx of steam. Mr. Bower began operations by using air alone, and one of his first experiments was the heating of a bar of iron, 1 in. square and 8 in. or 10 in. long, in the tunnel from a hot blast stove to the tuyeres. The temperature of the air was abont 1500 degrees. The bar became very strongly coated with a kind of brown oxide, and although it has since been exposed to all weathers, no corrosion has attacked it. Mr. Bower next tried heating the iron to be coated in gas retorts, and admitting fresh air to these retorts only about once in two hours. Curiously enough the first experiment he tried was perfectly successful, though about thirty subsequent experiments were failures. Had the first been a failure he would very likely have abandoned the pursuit, but its success encouraged him to proceed. Aided by his son, Mr. Anthony Bower, he persevered, and after the expenditure of much time and money he succeeded in devising means by which, as we have said, uniform results can be obtained. The magnetic oxide of iron appears to be always a secondary product; that is to say, the sesquioxide $Fe_2 O_3$ is formed first, and subsequently $Fe_3 O_4$, or the magnetic oxide, which, by the way, occurs "natural," is a valuable ore, and is the "loadstone" of old books. Availing himself of this fact, Mr. Bower first coats his iron with the ordinary oxide, and then converts this into the magnetic oxide. The process is extremely simple. An oven is constructed large enough to contain, say, a ton of the articles to be coated. In connection with this oven is a gas producer, somewhat similar to Siemens'. Any required quantity of air can be admitted, the air being previously heated to a high temperature, to the oven, which accordingly can be filled either with carbonic oxide from the gas producer, or with carbonic acid, or with carbonic acid and an excess of oxygen at pleasure. After the articles have been placed in the furnace, air mixed with carbonic oxide is freely admitted for some time, the car-

bonic oxide C O taking up another atom of oxygen from the air and becoming CO_2 with evolution of heat. The excess of air in the furnace or oven supplies oxygen to the iron, which becomes coated with Fe_2O_3. After a time the supply of air is shut off. The carbonic oxide then apparently abstracts oxygen from the iron, and Fe_2O_3 becomes Fe_3O_4, the wished-for oxide. Curiously enough, and for some unexplained reason, the most uniform results are obtained, not as might be supposed by first establishing a coating of red oxide of the required thickness, and then converting it all at once, but by admitting and shutting off air alternately at regular intervals throughout the process, which lasts from eight to ten hours. The consumption of coal is about 5 cwt. per ton of small castings coated. No skilled labor is required, as even if too much air is admitted no harm is done. The only duty devolving on the attendant is to fill the oven, to lute up the door, to attend to the gas producer, and to move a handle between two fixed points half a dozen times in the ten hours. Any handy furnace-man could learn how to work the process in two days.

As for the results, they are eminently satisfactory. To say that the black oxide is indestructible under ordinary influences of the weather is to state a truth known for many years to chemists. The articles which we have seen have a coating of this oxide, not existing there as a scale, but apparently incorporated with their substance. It would be but waste of time to point out the enormous advantage that will accrue from rendering cast iron castings as incorrodible, for all practical purposes, as gold. The end would be worth attaining at some trouble; but in the Bower process there is really no trouble. It will be remembered that Professor Barff found it necessary to scrub, wash, and pickle in dilute sulphuric acid, each article to be coated. In the Bower process nothing of the kind is required; the articles may be taken just as they come from the foundry, and they are none the worse for a thick coat of rust. For example, old lamp posts, which have stood out in the rain unpainted, iron pipes stacked about a yard for years, sewer traps, gas pipes, all go alike into the oven brown with common rust, and come out coated with the magnetic oxide. We have seen a 4 in. gas pipe which had been broken in two; one-half was coated, the other was not, and, when put together, at first sight it seemed as though one-half had been painted lead color, while the remainder was left in its original state. The power of converting the sesquioxide into the magnetic oxide is a peculiar and special advantage of the Bower process, and it is not easy to overrate its value. As some of Mr. Bower's foreign patents are not yet complete, we forbear for the present to illustrate the oven and gas producers which he uses, and about which there are certain ingenious features of detail which are essential to its successful operation. With a properly constructed furnace, there is, as we have said, no difficulty in producing uniform results with comparatively unskilled labor, and the whole cost of the process is so small that its use cannot fail to extend rapidly. The experimental apparatus at St. Neots hardly deserves the name, as it is a full-sized oven capable of containing at least a ton of iron. It is not necesssary that any care should be taken in placing the articles in the oven. The oxide is formed no matter how the articles are piled on each other. It is a curious fact that a chalk mark put on the iron before it is placed in the oven is found a chalk mark still when it is withdrawn, but the magnetic oxide is under the chalk. The special feature of the process is its simplicity of application. For a very moderate sum cast-iron can be rendered indestructible with certainty and dispatch. It is a fortunate circumstance that the color of the oxide, resembling lead, is far from unpleasing. The process would never have been popular had magnetic oxide been a brilliant red, or a dingy orange hue.

Some of the coated articles have been exhibited at the present meeting of the Iron and Steel Institute, and one of the exhibits is a length of rusty angle iron cut in two, one part left rusty as it was before, the other as it has been converted by the process, and the result is very striking. An umbrella stand is not only rendered incorrodible, but it is made, so to speak, "beautiful for ever," as it requires neither painting nor bronzing, and is, in fact, almost like a new

metal. Pots and pans have been coated with the process. Messrs. Smith and Wellstood, of Glasgow, the well known makers of American stoves, sent to Mr. Bower a furnace pan to be coated, and we cannot do better than use their own language in speaking of the result: "We take great pleasure in telling you that in our own judgment your process of oxidizing the surface of iron manufactures is a complete practical success in preventing the slightest appearance of rust. We have had in use and under test in every way we could think of for the last six months one of our portable cast-iron farm and laundry boilers—a 22 gallon size—coated by your process, and not a sign of the least rust or the slightest discoloration of pure clean water has any time shown itself, although the said boiler has several times been standing out of use with portions of water in it to induce rusting. Another test we have given it, and which satisfies us of its value, is by several times firing the boiler with only a small portion of water in it, thereby exposing all above the water-line to a strong heat, and without any perceptible injury to surface coating, and this is certainly what neither the galvanizing nor the enameling process would stand." Mr. F. J. Evans, the engineer of the Beckton Gas Company, gives similar evidence, and Mr. Joseph Kincaid, the tramway engineer, had a large quantity of stable fittings coated by the process last year, and he speaks in the highest terms of it, so that there is now no question of the success of the process after three years of incessant labor, under, at times, the most discouraging circumstances, and after great expenditure of money. It has grown up from a laboratory experiment to a process ready for application to industrial purposes, and fully entitling it to the favorable comments which we have passed on it.

IMPROVEMENT OF THE WATER SUPPLY OF LONDON.

From "The Builder."

The electoral struggle, on which the eyes, not only of England, but also of Europe, have been fixed with unexampled anxiety, has for a season diverted public attention from the great question of the water-supply of London. But this question will naturally be one of the first to come, in one shape or another, before the new House of Commons. There are signs in the air that various schemes, if not yet ripe to hatch, are in process of incubation. We have already seen, on more than one occasion, how great is the advantage possessed by those who come forward with a thoroughly-studied subject, over those to whom the study is new. And we are desirous that those who are, after all, the persons most deeply interested in this important question—namely the inhabitants and rate-payers of London—should not again suffer from a surprise.

We are convinced (and shall be able at the proper time to show good grounds for conviction) that so far from the three great requisites of adequacy, purity, and cheapness of supply being conflicting elements, no sound and well-considered scheme can be produced that shall advance either one of these objects without at the same time advancing the other two.

Public works in England, as a general rule, have been hitherto carried out on one of two opposite theories. The one is the theory of monopoly, the other that of competition. Each of these theories has its own advantages; each has also its disadvantages. Under a monopoly the expenditure of capital is likely to be restricted rather than excessive. Duplicate expenditure is avoided; economy is studied; but the public convenience is rarely fully consulted, and scientific and practical improvements are but slowly and grudgingly adopted.

Under the principle of competition this is reversed. The outlay of capital is apt to be wasteful; it is often two or three times the needful amount. Working cost is thus inevitably increased. On the other hand, the public convenience is so far studied as may serve to attract custom to one rival rather than to

another. Competition, involving the necessity of studying every source of economy, with a restricted income, tends to stimulate scientific and practical improvement.

Whether either of the two systems most conduces to the public safety, to say nothing of the public welfare, may be doubted. But the general upshot of competition in England, in matters involving much outlay of capital, has hitherto been combination. This method, by which the combatants agree to divide the spoil of the public among themselves, unites the disadvantages of both monopoly and competition, without necessarily securing the advantages of either. Wasteful outlay of capital, wasteful duplication of working cost, have been incurred. And when one competitor no longer strives to divert custom from another, the convenience of the public is likely to be little more studied than in the case of an original monopoly. In fact, the public, under combination, has to pay interest on a double capital.

Are we, then, at the mercy of these two defective theories? Have we no choice but that of monopoly, tempered by competition, till it gives birth to a more comprehensive monopoly?

We are not of that opinion. We are not of those who would fold their hands and cry, "What can we do?" We hold that there is another principle, and that it is the true theory on which the public works of the future can only be successfully carried out. For monopoly, on the one hand, and for competition on the other, we would substitute co-operation.

We may cite an example of the kind of co-operation to which we refer, in the case of the turnpike roads and highways of England before the introduction of railways. Here the State provided the road, and provided it well, and at a moderate cost. Some 130,000 miles of highway, of which 20,600 were turnpike roads, existed in England and Wales in 1873, affording an average length of 2.24 miles for every square mile of the surface of the kingdom. Of the cost no record has been kept. The writer of the article on the Civil Engineers of Britain in the *Edinburgh Review* of October, 1879, estimates that the sum of £160,000,000 barely represents the cost of the highways of England and Wales, and £220,000,000 that of the 197,836 miles of the United Kingdom.

The maintenance of the chief main highways — the turnpike roads — was effected by the traveling public. When traffic is thick this system acts well. When traffic is sparse it proves an intolerable burden. The abstraction of so much long traffic by the railways, in spite of the enormous impulse which they gave to that traffic, sounded the knell of the turnpike system. The present annual cost of maintenance, exclusive of urban roads, is calculated at £3,200,000 When the traveler is unable to maintain the road, the burden falls on the ratepayer.

In the third place, the actual carrying power was provided by individual effort. Sometimes aid of the nature of a monopoly was afforded to a man of enterprise, as in the case of Mr. Palmer, who introduced that excellent form of mail-coach, which was superseded by railways. Sometimes competition ran wild. There was a time when a traveler could be taken from London to Southampton for nothing—so keen was the rivalry between the opposition coaches. It is true that he had to pay double fare for his return to London. But, on the whole, in spite of various shortcomings, the service of our roads, in 1833, was all that could be expected, so long as horseflesh supplied the motive power and regulated the speed.

Here, then, the fixed half of the "dynamic pair," the road, was supplied by the State, that is to say by the whole country, and maintained either by the actual travelers, or by the potential travelers, that is to say the inhabitants of the locality. The motive power and plant were supplied by individual enterprise; and the public was well served. The inartificial arrangement had in it the true elements of co-operation, and answered accordingly.

We might easily show how the absence of that gentle control, which should so far aid private enterprise as to assure those who entered upon it against unwarranted and unprofitable competition, has strangled the growth of our railway system, and given to our original railway shareholders barely a third of the return received, with lower fares, by the original railway shareholders of France. We

might point to the great expense at which the French Government is now redeeming one of its few blunders in the legislation affecting the public works of France, namely, the establishment of a monopoly in favor of the Chemin de Fer du Midi by allowing the directors to purchase the Canal du Midi and the connecting waterways. But our present business is with the water supply of London. Here we have first, partial monopoly; secondly, wild and unregulated competition; thirdly, partial combination; and, fourthly, an attempt at the re-introduction of monopoly.

We do not propose to confine our views to general principles. The matter is of such importance to every Londoner that no amount of labor can be too great to obtain an exhaustive knowledge of the controlling elements. And here, instead of offering estimates of what may or may not be occasions or opportunities for future saving of cost, we propose to ascertain what, in every item of cost, is the minimum that at this time is actually paid over the great metropolitan province. On such accurate details alone can be based any reliable estimate of what we may expect as a future minimum burden on the ratepayer, when the true principle of co-operation shall have been brought to bear on a well-organized system of supply.

We need not now go into the history of the original monopoly of the New River Company, in which his most gracious Majesty King James was a sleeping partner, enjoying a half share. Neither will we now pause to tell the tale of competition warfare, of costly Parliamentary struggles, and of the coalition of opposing interests. We take the supply of London as it now is divided among eight companies of various magnitude; noticing here that a mark of the waste of money incurred by competition is to be noted in the fact that out of the 117½ miles of the metropolitan area, six miles are jointly shared by two companies. In other words, the work is done twice, instead of once, over those six miles, and that at the cost of somebody.

Taking the eight areas which lie outside the disputed six miles, we find the next sign of the wasteful cost of competition in the different ratio of capital laid out in different districts. As it is not our aim in any way to affect the market price of the stock of any company, we shall omit the names while giving the most instructive facts. Over one district, then, in which it may be presumed competition has been but feeble, the sum expended by the water company in providing for the wants of the inhabitants has been 2.17*l.* per head. In another, the tale of Parliamentary conflict is briefly told by the announcement that the outlay of capital has been 5.20*l.* per head. Ranging between these two figures, the average outlay of capital per unit of the population served was, in 1877, 3.05*l.* per head. It may be safe to set down ten shillings per head, or one-sixth of the actual cost, to the account of that legislation which permitted, not to say encouraged, a wanton competition.

The returns now annually made to parliament of the accounts of the various companies are of value as statistical data. But they are not in a shape—few Parliamentary returns are—to give their full meaning to the reader. They demand, for this purpose, the work of the expert. For this reason they are but little referred to by the press, notwithstanding the important lessons to be deduced from their figures. It has been our study to present some of the outcomes of these returns in a manner that may be readily grasped by every reader; and after consideration, we have arrived at the conclusion that the best unit of comparison to take is the metric ton of water delivered to the householder, or, at all events, sent into the mains of the company for such delivery.

The largest supply of water that has been delivered in the mains of the companies in any recorded year was in 1874, when it amounted to 34.3 gallons per diem per head of the population. This is equal to 56.8 metric tons per head per year.

The smallest ratio of supply recorded was in 1869. It was 31.4 gallons per head per diem, or very nearly 52.1 tons per head per annum. A ton of water per soul per week, in round numbers is thus an ample allowance, and one from which the departure is not, practically, very great; 37.7 gallons per head per diem for a month together is the highest rate of delivery that we have found

recorded. This was in August, 1873; 29.4 gallons per head per diem is the lowest monthly average within the last ten years; that was the rate in December, 1869, and also in December, 1876. It follows that the ton of water delivered is an unusually equable unit for calculation.

Now if we allow only 5 per cent. on the capital laid out (in works and also in Parliamentary costs) by the various companies, we find that it amounts, in the case of the largest capital outlay, to 1.325d. per metric ton of water delivered; and in the case of the cheapest provision, to no more than .530d. per ton. These figures do not coincide with the capital cost per head, because there is a considerable variation, amounting to as much as 40 per cent., between the quantity of water per head supplied by different companies. It is probable that this difference closely represents waste; but we give it as it stands. It is worthy of note that the difference between the quantity of water supplied by the companies delivering the largest and the smallest mean per soul, is very nearly identical with that between the maximum and the minimum supplies of the average of the eight companies taken all the year round.

The minimum charge per ton of water incurred for capital in any case is .63d. per ton, a figure which would be reducible to .53d. per ton if only 5 per cent. were paid on capital. The average charge for capital is about .893d. per ton; and the maximum rises to 1.45d. per ton, or within a fraction of the mean total price of 1.475d. per ton charged all round and covering all expenses. But the highest price per ton is received by the company which supplies the smallest tonnage per head; so that this really lucrative return is no doubt in a great measure due to the prevention of waste.

We shall therefore not be very wide of the mark if we allow the price of six-tenths of a penny per ton of water delivered as one which should be regarded as the normal maximum to be kept in view for London for interest on capital. This, however, is without prejudice to a plan for a future extinction of such capital. In round numbers, the actual charge is half as much more, or .9d. (exactly .803d.) per ton.

As to working expenses we must first consider those which, under any system of management, are directly proportioned to the quantity of water delivered in the mains. That, as we have before hinted, may possibly be a very different quantity from that delivered in the houses. These items are pumping and filtering. Their cost is influenced, in no small degree, by the difference of level between the source from which the water is taken, and the height of the ground over which it is delivered. Thus, while the cost of the two items, averaged for all the water companies of London, is .183d. per ton, it rises to the maximum of .234d., and sinks to the minimum of .085., chiefly owing to differences of level. There is reason to suppose that, over a certain and a not inconsiderable area, the pumping expenditure might be reduced by a better mode of districting. On the other hand, the cost of filtering ought rather to be increased than decreased. And the due provision for supply under pressure in case of fire is a provision that may enhance the cost of pumping in some cases. We ought not, therefore, to set down this mechanical cost at less than the present average of .183d., or, in round numbers, two-tenths of a penny, per metric ton of water delivered to the consumer.

Management varies from .076d. per ton (in two instances) to .167d. and .170d. per ton (in two others). The wealthiest companies pay the most for management. The average charge is .119d. per ton. There does not seem to be any reason why, if the whole system were arranged in the best possible manner, the cost of management should exceed eight-hundredths of a penny per ton of water.

Maintenance, and and all expenses but those before mentioned, cost, on the average of the eight companies, .280d. per ton. The lowest rate is .209d.; the highest, .414d. The price of .249d. is the lowest but one; and we may probably be justified in taking that figure, or say .25d. as a normal price and under a perfect system of management.

We thus have the following elements of cost as they may be ranged under the system of monopoly, competition, and scientific co-operation:

COST PER METRIC TON OF WATER.

	Government Bill.	Actual.	Possible.
Dividend and Interest...	1.500	.900	.600
Pumping and Filtering...	.200	.200	.200
Other working expenses.	.225	.225	.250
Management and Collect'n	.120	.120	.080
	2.075d	1.475d	1.130d

The decimal of other working expenses are, it will be seen, reduced by our taking the other items in round figures.

We have here before us, far within the limits of practical accuracy, a conspectus of the cost at which a ton of water may be delivered to the consumer over the metropolitan area. The actual average price of three-halfpence cannot be considered as exorbitant. It should be noted that the supply per soul delivered by that company which has some sixty per cent. of its deliveries under constant services is four per cent. below the average—and that in spite of a large consumption for trade uses. And we cannot call too much attention to the fact that it is only on the principle of co-operation that an attempt is likely to be made to reduce both quantity delivered and price per ton. As matters now stand only about one-seventh of the cost of the water to the public is affected directly by quantity. As much capital, as much establishment, as much cost of of every kind, except pumping and filtering, or, at least, almost as much, is incurred in the delivery of the 29.4 gallons per head per diem of the winter as in that of the 37.7 gallons per head per diem of the summer. If companies are paid by charge on rental, they will seek to deliver as little water as possible. If they are paid in any way by metric tonnage, they will endeavor to deliver as much as possible. Their interests, in this particular, are not identical with those of their customers.

As to the manner in which the principle of co-operation is to be brought to bear on the arrangement of these complicated interests, we have no space now to enter into the investigation. But we may point out the existence of the elements of co-operative success. First, there is great, certain, and increasing demand. A sound scheme has this sound basis. Under any conceivable circumstances the Londoners are able and ready to take, and to pay what is necessary for, let us say, 26 metric tons of water per head per annum. This is an ultimate fact, and on this fact, not strained, but duly regarded, all calculations must be based.

Secondly, we have the state to a certain extent already concerned in the affair. the State has conceded certain rights, which it is bound to respect, where the conditions have been observed. The State must be the arbiter of what is to be done when those rights have reached their limit.

Thirdly, we have a vast machinery, already provided by competition, the utilization of which will be made more advantageous by substituting the principles of co-operation. It is obvious, to take a single example, that nearly twice as much money must be spent in supplying water to those six miles of area which are jointly supplied by two companies, as would be the case if they were supplied only by one. In the same way any attempt to introduce a new competing means of supply, instead of controlling and consolidating the existing ones, can only end, if it have any success, in laying the burden of extra capital outlay on the ratepayer. It is mainly in that districting by zones of level, which must form a part of any real improvement in the hydraulic arrangements of the London water supply, that, as we have seen, economy is to be effected. At the same time, we regard one chief advantage to be the means of obtaining a perfect control for the extinction of fire.

Again, as to the source of supply. Even apart from any question as to the water of the Thames, the sources of the deep wells at Deptford, at Plumstead, at Charlton, at Crayford, at Shortlands, and at Belvedere; of the Chadwell spring; of the wells at Ware, Amwell, Cheshunt, Hoddesden, and Wormley, and of the river Lea, are acquired to London, and must form a part of any future system of water supply. We have before indicated the green sand underlying the valleys of the Wey and of the Mole as a future source of ample supply of the very purest water. The rainfall over the Wey basin alone amounts to nearly five

times the entire annual consumption of London. Not a third of that runs through the channel of the Wey. Much of what is not evaporated must thus make its way through the pervious subsoil to the valley of the Thames. In 1828, Mr. Telford reported to Parliament in favor of the utilization of the waters of the Ver and of the Wandle. Long familiarity with the district leads us to add the names of the Gade and of the Chess. With sources of supply like these at command, it is worse than idle to talk of saddling the ratepayers of London with prodigious works for tapping the cradle of the Severn or of the Wye, with the result of doubling the present charge for interest on capital—interest which, one way or another, has to come out of the pocket of the ratepayer.

By due co-operation of the State, the companies, and the consumers, we are convinced that it is possible to give to London a constant supply of pure water at a working charge of less than six-tenths of a penny per ton, exclusive of interest on money; and further, by judicious forethought, to extinguish the cost of the capital within little more than half a century, without any increase of the present burden on the rate payer.

PURE WATER.

From "The Architect."

"Water, water everywhere, and not a drop to drink," or rather, that is fit for drinking, is a cry only too frequent both at home and abroad. From rivers polluted with the sewage of towns the water supply of great cities is often drawn. Wells reeking with surface drainage are relied on in rural districts, and only when an outbreak of typhoid or enteric fever arouses the inhabitants from their lethargy is the death-dealing scourge traced to its true source—impure water.

What is the antidote? Filtration, by some system which shall be not only mechanical, but chemical in its action. This end seems fully attained in the "Silicated Carbon Filter" produced by the Silicated Carbon Filter Company, of Church Road, Battersea. In a recent visit to the works we had an opportunity not only of seeing the material in the raw state, but also the modes of manufacture, and of examining filters suitable for many purposes, from the purification of the water supply of towns to the siphon filter for the use of travelers.

To begin at the beginning, the carbon used by the Company is neither vegetable charcoal, liable to become foul with increase of temperature, nor animal charcoal, prone to generate animalculæ, but a mineral carbon free from the defects of both.

The construction of the silicated carbon filters, though modified in slight details to suit exceptional emergencies, has one fixed basis. The upper and lower layers are invariably slabs of mineral carbon moulded when moist, and then subjected to hydraulic pressure until they become a dense mass, to be finally indurated throughout by the action of fire into hard, solid cakes of homogeneous structure. The middle layer also consists of mineral carbon which has been subjected dry to hydraulic pressure, forming a mass which, from its lesser density, offers minor resistance to the free passage of the water, thus permitting greater rapidity of filtration with equally satisfactory results. The "saggers," destined to hold the mineral carbon slabs, are formed of Stourbridge fire-clay, moulded on the premises into tubes varying in size according to the cakes they are to take, and pierced round with small holes to provide for the escape of gas evolved in the process of firing. In these "saggers" the carbon is packed in granulated carbon, to prevent touching, in various sizes, from the tap or "faucet" filter, in use in the States, of half an inch in diameter, to the filters for brewers' use or the water supply of towns, made of any required dimensions. The necessary number of "saggers" being filled, they are placed in a kiln with two fires, having an inner lining to protect them from the direct action of the flames. In this kiln they are kept at a white heat for some days,

then, the fires being drawn, they are left to cool gradually until their temperature has moderated sufficiently to permit the "saggers" being handled by workmen, whose hands are protected with thick leather gloves. When quite cool the lower slab is fitted into the filter by cement, the dry layer placed over it, and above all the top slab is fitted and cemented down, so that all is made air-tight.

The brickwork of the kiln is banded with great hoops of iron. Opposite the door, built up of fire-bricks, after the kiln has received its full complement of "saggers," and cemented, is a strong bar of wrought iron set tight by a screw. This bar must needs be strong, for the intense heat so expands the brickwork and iron bands that, at the height of the firing operation, it has to bear a pressure of no less than 60 tons. Were it to snap, the whole structure would burst to pieces, and a chaos of mingled brickwork and iron take the place of an orderly array of "saggers," set in rows within a solid superstructure of bricks, built up on foundations, radiating like the spokes of a wheel, set up on a solid bed of cement. This is the process adopted for all the filters. In the brewers' filter there is a third hard slab inserted in the center of the filter, between two soft layers.

Taking the water supply of towns, it seems a strange circumstance that the practical philanthropy of Kyrle, the Man of Ross, of whom Pope sang, should still hover over the place he loved so much, and that the little Hereford town should set a sanitary example to many more pretentious rivals. Some time ago an artesian well was sunk. The water from this is pumped into a reservoir situated on a hill overtopping the town. Lower down this height two "brewers' filters," with double cylinders, are fixed at the level of a second hill, over which the water, finding its level, passes, and thence descends, thoroughly purified, to supply the houses and the local breweries of the pretty town of Ross. The construction of this "brewers' filter," adapted for either high or low pressure, is excessively simple. There are two taps both above and below, the filter being in duplicate, with one pipe for outfall at the back. For cleansing, by simply altering the position of the taps, a reverse action takes place. The water is forced backward from one filter to its companion, and the stream of filtered water sent through carries away any impurities which may have collected on the face of the carbon. They cannot pass through, owing to the indurating operation in the kiln. The filter can be connected with a cistern or reservoir, or attached to the main service pipe. No attention is needed save as before said, an occasional opening of the cleansing taps, and the supply ranges from 100 to 2,000 gallons, or a still larger quantity, according to size. A main-supply filter on similar lines, but with a single cylinder, is specially adapted not only for breweries and distilleries, but for soda-water factories, large mansions, schools, hospitals, dye works—in fine, all establishments where a large and constant supply of pure water is required. It speaks much for the estimation in which the silicated carbon filters are held, that throughout Messrs. Huntley & Palmer's biscuit bakery, at Reading, where two thousand people are employed, these filters are fitted up, no water being used in the manufacture of their various products, which has not passed through silicated carbon.

The latest development of the system is one adapted specially for hospital use, or wherever it is desirable to have a series of separate filters. The filter is fastened upright by a bracket to a wall; the supply enters at the bottom, the filtered water being drawn off from the top, reversing the usual process, the cleansing tap being below. This filter commends itself specially to households where space is an object; for butlers' pantries, still rooms, &c.

So much for the fixed filters. There are many varieties of those which are movable, from the dining-room filter in marbled china to the canvas filter for bullock wagons, or the neat nickel case to be slung over the shoulder of a pedestrian in lieu of an ordinary flask. The dining-room filter, can, when desired, be furnished with an ice compartment, ensuring a constant supply of water, pure and cold. Some can be had of a more expensive kind, made in frosted glass or in a porous clay, acting as a refrigerator, in shape and hue resembling an Etrus-

can vase, from which indeed the model has been taken. These are provided with a movable pan, into which the silicated carbon is fitted. By this means the exterior can be cleansed daily without inconvenience. For table use filters are likewise made in porous clay in two portions, the upper containing the filter, the lower being the ordinary "gurrah," "chattie," or "monkey"—to give their East and West Indian *soubriquets.* For hot climates the "refrigerator filter" has been made; without is the case—within a filter fits, the space between being filled with ice, or salt and water. The tap for the filtered water passes from the interior filter through the outer case. Above is a ring which, being pressed down on a flannel covering, keeps both the water and the cooling medium from contact with the air. The melted ice can be drawn off below when needed by a special tap. This peculiar filter is a favorite at Ceylon, the firm making large consignments to Colombo.

A quaint filter in use in the Havana is cone-shaped. The cone exteriorly being of the indurated carbon; the interior of the dry compressed layer. This is simply slung up in a corner, the water being allowed to drip into a "chattie" beneath. Another filter much used in Cairo and Alexandria, and entitled the "double action," is adapted for rain or muddy water. "Old Nile," sacred river though he is, carries so much of the earth in his composition, that any ordinary filter would soon clog under the deposit of mud left by the turbid water. To prevent this the filter proper is protected by a cap or slab through which the water must pass. The rough impurities are therefore left on the first obstacle, which can be removed in a moment and cleansed with a sponge, and the water is thus doubly filtered before use. The same filter is well adapted for the peculiarities of the great American rivers, where a large amount of earth is held in solution.

For the "rough and tumble" usage that filters are subjected to on shipboard and in barrack-rooms, a hard stone-ware filter is specially made, strongly encased, cover and all, with stout wicker-work, and provided with handles for easier carriage. Filters of this pattern are supplied to the Admiralty, the War Office, and various lines of ocean steamers, including such well found vessels as the "Green line," the ships of Messrs. Donald Currie & Co., and troopships like the *Jumna.*

Another provision for the health of the army is provided in the "ambulance filter." Let any one read about the difficulties of obtaining potable water on a campaign in such books as Chaplain Hare's "Journal," or Archdeacon Coxe's "Story of the Campaigns of Marlborough," or the volumes of the historian of the "Peninsular War," and he will at once see its advantages. The "ambulance filter" is simply silicated carbon fixed in a white metal case, provided with a perforated cover to keep off the coarser impurities. To this is attached a vulcanized india-rubber pole, with a tap. That is all. It cannot get out of order, and is set in action solely by exhausting the air from the tube. By means of these filters the foulest water could be rendered palatable, even were the wells poisoned the water would become innoxious, whether the bane was vegetable or mineral, strychnine, antimony, or arsenic. That this is no mere assertion is proved by Mr. Wanklyn's experiment. He dissolved a grain of strychnine in a pint of water, filtered it through silicated carbon, drank one half of it with impunity, submitting the remainder of it to chemical tests, when not a trace of the poison was discovered.

An equally simple system of purification is supplied in the canvas filter. This is merely a long canvas bag, provided at top with a canvas cover, at bottom with a wooden tap. The carbon being placed in the center, it is only necessary to fill the upper portion, sling the bag, provided with a rope handle for the purpose, to the bullock wagon, and the water is purfied *en route,* while it is kept cool by the porous texture of the material. For verandahs in either the East or West Indies, for huts in the Australian bush, for camping-out parties at home, or at the great Divide when out for "big game," this filter is alike useful and unbreakable. When not in use it folds up flat into but small compass, the weight is a mere trifle, and it is always ready for use.

Having started with the water supply

of towns, and indicated the various uses to which the filters can be applied, we may now describe the smallest modification of the system, or the "siphon filter" for travelers. Its latest form is for carrying over the shoulder, as supplied to the forces in the "promenade militaire" in Abyssinia, to the Ashantee expedition, and to the forces in Zululand. A dainty arrangement, strongly recommended by the Horse Guards for officers' kits, and enclosed in a nickel-plated case, has been specially designed by Major Fraser, R. E. Travelers know by sad experience the danger incurred in drinking the water in many Continental cities. At the expense of a few shillings they may carry a pocket friend with them, at once a safeguard and a convenience.

This, then, is a synopsis of the various filters manufactured by the Silicated Carbon Filter Company at their works. The operations of preparing the carbons —firing and fixing, producing the "saggers," turning the filters and "chatties" in porous clay, packing and casing—are all carried on under supervision, in such a way that defective workmanship is impossible in any of the filters which leave the works.

THE EFFECT OF SULPHATES ON LIME MORTAR.*

From "The Builder."

In the year 1870, the author commenced to experiment on the subject of the effect of sulphates on lime mortar, and finding himself at the beginning of 1879 unable to further pursue his investigations, he decided to submit a paper on the subject to the Institution of Civil Engineers, with a view of enabling others to give the matter their consideration. It afforded him pleasure to find that that body appeared to appreciate his labors, inasmuch as it accepted the paper and set it up in type. However, as twelve months had elapsed and there was no appearance of the paper being read this session, the author determined to withdraw it, and by the kind courtesy of the Council of this Association he is enabled to bring it before the present meeting.

It was observed by Major, now Major-General, H. Y. D. Scott, C.B., Assoc. Inst. C.E., about twenty-five years ago, that the chemical combination of a small quantity of sulphurous acid gas with limes had the effect of causing them to set, after the manner of cements, without increase in bulk or any considerable elevation of temperature. The union of the gas with the lime was first effected by allowing sulphur fumes to pass into the kilns during the process of calcination; but more regular results have since been obtained by mixing either a soluble sulphate or sulphuric acid with the lime after it has been burnt. In ordinary mortar the lime, before being mixed with the sand, is brought to a state of fine division by slaking with water, that is chemically; whereas in General Scott's method mechanical appliances are resorted to in order to reduce the lime to powder, and water containing finely-ground plaster of Paris or other soluble or partially soluble sulphate is then added. When these have been reduced to a creamy paste, the sand is put in along with any further quantity of water necessary to render the mortar when mixed convenient and fit for use. Mortar thus prepared may be used even for plastering purposes shortly after being mixed, as the lime when treated in this manner shows no tendency to slake. The quantity of sulphate required to be added varies with the description of lime, and is much governed by the proportion of clay which it contains. Those limes in which only traces of alumina are found, such as the pure chalk limes, require about 7 per cent., whilst blue lias and other hydraulic limes require but 3 or 4 per cent., and with very clayey limes the amount of sulphate may be reduced to 2 per cent. of the bulk of the lime. The principle of General Scott's invention, now generally known

* From a paper by Mr. Graham Smith, C. E., read at the Annual Meeting of the Association of Municipal and Sanitary Engineers and Surveyors, held at Leeds, on May 27th, 28th and 29th.

as the selenitic process, is so to combine the lime with water that it shall not burst with the heat, and, in fact, to arrest the slaking of the lime so that the setting may take place without increase in its volume. By this means the strength of the mortar is increased, and it is rendered quick-setting, which is a very desirable property under many circumstances. In ordinary building operations, however, the mortar must not be too quick, or it may set before it can be got into the work. A strong, but comparatively slow-setting mortar is often, therefore, to be preferred. The experimental results contained in this paper lead the author to believe that such can be procured by first thoroughly slaking the lime with water, then adding the sulphate to it in that state, and afterwards the sand, ashes, and pozzuolanas, or other ingredients, and mixing the whole in the usual manner. If this method be pursued, and four or five parts of sand be added to one part of slaked lime, a slow-setting mortar will be produced, possessing after having set for some time much greater strength than selenitic or Portland cement mortars containing a similarly large proportion of sand. The characteristics of this mortar are therefore entirely different from those of the latter compositions. It would appear that General Scott entirely directed his attention to the neutralization of the slaking properties of quick lime, and not to the employment of a sulphate with slaked lime, as here proposed, in mixing ordinary mortar.

The adding of plaster of Paris to lime has frequently been said not to be a new process, inasmuch as it has been used by builders for an indefinite period both with and without lime for plastering purposes, in order to produce a fine quick-setting mortar. The proportion of plaster employed for this purpose, however, has always been much larger than that adopted by General Scott, and proposed to be used by the author. The builder has hitherto mixed a large proportion of plaster with lime on account of its quick-setting properties as a material, and employed the resulting composition for rendering the interior of rooms and similar descriptions of work not exposed to wet or damp; and in such positions, were it not for the question of cost, many would prefer to use neat plaster of Paris. This mortar prepared with plaster of Paris if subjected to wet or damp would crack and disintegrate, whereas that which the author advocates is suitable for all situations in which it is customary to employ an ordinary mortar. The plaster of Paris, that is, sulphate of lime, is added in small quantities, because it is the most convenient and economical medium for supplying the requisite chemical constituents. The builder would deem plaster which has been once set as worthless; however, it may be inferred, that if this substance were re-ground, it would answer in the processes which are now being considered nearly as well as fresh plaster of Paris.

In 1870 the author, then having charge of the testing of the various cements and mortars employed in the works in progress at the Liverpool Docks, availed himself of the facilities thus placed at his disposal, to test the effect of mixing sulphates with slaked lime. The results being somewhat extraordinary, it has been thought advisable to bring them in detail before the Institution. The lime used in the experiments, unless otherwise pointed out, was Halkin lime, from Flintshire, in North Wales. The limestone from which this lime is derived contains about the same amount of silica and alumina as that from Barrow, and produces an hydraulic lime, which, however, is not equal to Warwickshire blue lias lime in setting or hydraulic properties. The proportions given in the accompanying tables are in all cases by volume; and where the quantity of any ingredient is represented by a fraction, such is of one part and not of the whole quantity of mortar. The quantity of plaster of Paris in all experiments with Halkin lime was a percentage of the quantity of slaked lime. The various descriptions of mortar tested were mixed in mills on the site of works in progress, and by men daily employed upon such duties; and every endeavor was made to insure that the experiments should be carried out under as nearly as possible similar conditions in each instance.

The first series of experiments was with briquettes having a sectional area of $2\frac{1}{4}$ square inches, such as usually

made for testing Portland cement. These were drawn asunder by means of a Michele lever cement-testing machine. [The results and all particulars were given in tables.] . . . . It remained to be seen how the addition of plaster of Paris would affect mortar intended to be set under water. Experiments tended to prove that the ultimate strength of the ordinary Halkin mortar was not impaired by immersion in water, but that the strength of the mortar containing a small percentage of plaster was materially reduced. It would appear from these experiments that by adding plaster of Paris to slaked lime the strength of the mortar will be increased and the cost reduced, consequent on the larger proportion of sand which may be employed; and it may be inferred that experience will demonstrate the advisability of employing plaster of Paris in mortar to be used in ordinary building operations, but that it would not be found advisable to add it to slaked-lime mortars intended for hydraulic purposes.

The author does not wish it to be understood that he considers any description of lime-mortar can equal in strength or setting properties neat Portland cement, or Portland cement mortar, in which a small proportion of sand is used. However, when a large admixture of sand is made slaked-lime mortar prepared with plaster appears to be decidedly stronger than Portland-cement mortar containing a similarly large proportion of sand. Even ordinary Halkin-lime mortar, when mixed in the proportions of 2⅓ to 1, at the age of six months, is about equal in strength to Portland-cement mortar mixed in the proportions of 4 to 1.

It may, on the whole, be taken for granted that mortar composed of four or five parts of sand to one part of slaked lime can be made possessing greater strength than Portland-cement mortar mixed in similar proportions. The economy to be effected is evident when it is considered that the normal price of Portland cement is not less than 2*s.* per bushel, whilst a bushel of slaked lime does not cost one-third of that amount.

The broken portions of the briquettes with which the first series of experiments was made have been exposed to the weather since 1871; those mixed in the proportions of five parts of sand to one part of slaked lime give evidence of being sound material, and of having stood equally well as those mixed without plaster in the proportions of 1 to 2⅓.

In making mortar the proportions of sand, ashes, and other ingredients which ought to be adopted, depend entirely upon the nature of the lime; for instance, no engineer would put as much sand with blue lias as with gray-stone lime. In the process now proposed similar laws will hold good, but, as a general rule, double the quantity of sand may be used when plaster is added, that would be considered proper with any particular lime under ordinary circumstances.

In conclusion, it may be stated that nearly 800 experiments with bricks and briquettes, carried out in various manners, tend to indorse the general results accompanying this communication and the opinions advanced, which are briefly: that the ultimate strength of all lime mortars will be much increased by the addition of a small percentage of plaster of Paris, and that, when mixed in the manner described, they will apparently at first possess similar properties to ordinary mortar made with the same kind of lime in the manner as at present practised.

Preserving Steel from Rust.—The composition of Mr. W. C. Woodhams, of Long Acre, gives good results. It is composed of Russian Tallow, 22 parts; hog's lard, 75 parts; castor oil, 1.25 parts; camphor, 0.25 part; palm oil, 1 part; annatto, 0.5 part; =100 parts by weight. The camphor is first reduced to powder; the lard and tallow are then heated together, and the oils, annatto, and camphor are added, and thoroughly amalgamated. The composition when cool is ready for use; it may be applied by means of a cloth to the substances to be preserved. In some instances other dye or coloring matter may be used instead of annatto. The composition prevents the action of sea-water upon metals. When it is to be used for hot climates, and in order to lessen its cost when it is to be employed for covering large articles, the proportion of lard is reduced, a corresponding amount of white resin and wax being added in its place.

REACTIONS IN THE OPEN-HEARTH PROCESS.

By ARTHUR WILLIS, F. C. S., Landore Siemens Steel Works, Swansea.

From "Engineering."

In this short paper it is not my intention to enter into the details of the construction of the open-hearth furnace, these having been so often and so ably described on former occasions, but to confine myself to the behavior of the metal in the furnace from the time the charge is melted until its completion.

Steel from the open-hearth furnaces, as is well known, can be produced either from:

1. A mixture of pig iron and scrap.
2. Pig iron and iron ore without any scrap.
3. Pig iron, scrap, and iron ore.

All these methods can be employed with advantage, but the most usual is the third—not that there is any special need to use scrap, but because it utilizes all scrap produced during the different stages of manufacture. In the Bessemer process carbon, silicon, and manganese appear to be eliminated uniformly. In the open-hearth process the degree and the time of elimination are quite different.

During the time the charge is passing into the fluid state, carbon, silicon, and manganese are all more or less oxidized, about 50 per cent. of the total amount contained in the charge, varying slightly with the temperature of the furnace.

As soon as the whole of the charge is fluid, the carbon remains almost if not entirely stationary, until the whole of the silicon and manganese are oxidized, which process takes from three to four hours.

During the time occupied by the oxidation of the silicon and the manganese—no gas being given off—the metal in the bath remains tranquil. When the silicon is reduced to about 0.02 per cent., and the manganese has disappeared entirely, the oxidation of the carbon commences, and the evolution of carbonic oxide throws the metal into violent ebullition, described by the melters as "being on the boil." This ebullition continues more or less until the carbon is reduced to 0.10 per cent. or under, when the metal becomes perfectly quiet, and the slag, which half an hour previously had been of a brownish tinge, begins to blacken from a slight oxidation of the metal.

From a number of analyses referring to the oxidation of carbon, silicon, and manganese, during the different periods of the process, I have selected two.

No. 1 was an ordinary pig and ore charge with about 25 per cent. of scrap. No. 2 was a similar charge as far as composition was concerned, but after the pig and scrap were melted sufficient spiegeleisen was added to give by calculation 1.5 per cent. manganese. Samples of the metal in each case were taken every half hour and carefully analyzed with the following results:

No. I.

	Carbon per cent.	Silicon per cent.
1	1.00	1.281
2	1.00	1.118
3	1.00	.506
4	1.00	.326
5	1.00	.232
5	1.00	.046
7	1.00	.020 on the boil
8	.80	
9	.55	
10	.44	
11	.25	
12	.18	
13	.10	
14	.06	

No. II.

	Carbon per cent.	Silicon per cent.	Manganese per cent.
1	1.34	1.60	1.40
2	1.34	.910	.792
3	1.34	.260	.100
4	1 34	.140	
5	1.34	.080	
6	1.34	.023	
7	1.34		
8	1.24		
9	1.10		
10	1.00		
11	.90		
12	.68		
13	.50		

When pure ore is used, no appreciable alterations takes place in the percentage of sulphur and phosphorus contained in the pig and scrap, but of course it is necessary to employ only the purest. Ores containing sulphate of baryta in large quantities are an exception, but it should always be looked for and such ores carefully avoided. In an experiment made with an ore of this description, 30 per cent., of the sulphur existing as sulphate of baryta was added to the metal. Several experiments were made some time ago on a series of charges at Landore from the same cargo of pig iron—a No. 1 hematite—and ores from various districts, no scrap being used in any of the charges, and the following results were obtained:

Name of Ore used.	Sulphur in Pig Iron.	Sulphur in Finished Steel.
	per cent.	per cent.
Elba..........	0.025	0.032
Marbella......	0.025	0.064
Sommorostro..	0.025	0.025
Mockta.......	0.025	0.025
Tagus........	0.025	0.064
Soumah	0.025	0.048

To insure that the pig iron was not mixed, samples were taken in each case when the metal was melted, and it was found uniform throughout.

M. Pourcel, at the last meeting of the Institute, stated that steel made from ore charges was unsuitable for plates. I can only say that the whole of these charges were manufactured into plates, which had a breaking strain of from 27 to 29 tons per square inch, and elongated from 25 to 30 per cent. in 8 in.

The pig iron most suitable for the open-hearth process—the sulphur and phosphorus being low—is that containing the least carbon and silicon. In the first place it contains a higher percentage of iron, and, in the second, it does not require to be so long in the melting furnace before the metal is completely decarburized. Moreover, pig iron containing a large percentage of silicon, although it is all oxidized, invariably yields inferior steel. Why, I cannot say. More than 0.50 per cent. of manganese is objectionable, not only on account of the delay it causes, but because of the destruction of the silica bottom by the formation of a fusible silicate of manganese. It is not only difficulties that can be explained, that a metallurgist, dealing with what may be called this mysterious compound steel, has to contend with, but also those which our present knowledge fails to account for. From long experience I find that steel from different brands of hematite pig iron, chemically the same, and made from the same ores, not only act differently in the furnace, taking more time, cutting the bottom, &c., but in their finished state show a marked difference in their tensile and other tests. At first I was inclined to impute this to some defect in the mode of analysis, which failed to detect minute traces of elements, possibly derived from the coke or limestone used in their manufacture; but, in contradiction to this, I found that two cargoes of pig iron of different brands, both of which worked in a most unsatisfactory manner by themselves, gave, when mixed in equal proportions, results which were everything that could be desired. Others invariably gave good results *per se* and, by mixing as many brands as possible, uniform results may be obtained.

Experiments made at Landore show that no metal added to the bath of steel has the slightest effect, as far as the elimination of sulphur is concerned, and manganese is the only metal that will counteract it.

Manganese has been described as a cloak for bad material. No doubt this is so to a certain extent, but at the same time its presence is indispensable in steel made by an oxidizing process. An ingot from a charge composed of Swedish pig iron, and puddled bar made from the best hematite pig containing no manganese, will break into pieces at the first blow of the hammer; whilst a similar ingot, containing 0.08 per cent. manganese, will forge.

Tungsten alloyed with steel appears to harden without detracting from its toughness, but I doubt much whether the advantage gained compensates for the cost. Tungsten is also said to add to the magnetic power of steel, but of this I have no experience. In steel supplied to a Cornish mining company from Sheffield for borers, I found as much as 10 per cent. of tungsten.

As far as fracture goes, this alloy is the most beautiful of all steels.

I have no experience as to the effect of tin on steel, but a bar of iron made from tin-plate shearings, from which the tin had been to a considerable extent removed, was extremely red-short and unweldable; the amount of tin contained in this sample was 0.15 per cent. Lead and zinc, when added to a bath of steel, are simply volatilized, without producing any effect except that of half-choking the melters.

Chromium gives great hardness, but at the same time causes brittleness, and may be put down as useless.

The effect of copper upon steel seems to be greatly exaggerated in most metallurgical works; it is generally stated to cause more red-shortness than the same amount of sulphur. In some experiments made at Landore, it was found that 0.10 per cent. of copper produced no appreciable effect on the quality of steel; and even when the amount was increased to 0.30 per cent., only a slight cracking on the side of the bloom was observeable. This question is, perhaps, more important than appears at first sight. One possible difficulty that soft steel manufacturers will have to contend with will, no doubt, be the scarcity of manganese ores suitable for the manufacture of ferro-manganese, and many good ores might be rejected on account of the presence of copper, a very frequent companion of manganese. At the present time ferro-mangenese containing 5 per cent. of copper would certainly be unsalable, although, in my opinion, it could be used with impunity.

In conclusion, I may remark that any comparisons made by me of the merits of the two great processes for making steel, *i. e*, the Bessemer and Siemens—would doubtless be considered prejudiced; but I believe it is now generally conceded that for soft steel the latter carries off the palm, and this I attribute to the complete elimination of the silicon, to the mixture of different brands of pig, and to the absolute certainty with which the carbon in the finished steel can be controlled.

THE STEEL OF THE FUTURE.

From "The Engineer."

Two parties exist, distinguished by holding different opinions concerning the steel which will be made in the largest quantities in a few years. One of these parties maintains that steel will become stronger and stronger, and that it is not only impossible, but is extremely likely, that in half a dozen years or so it will be stipulated in contracts that steel plates shall not have a less tensile strength than 35 tons to the square inch. The opposite party holds that it is not only impossible to produce a really ductile steel having so high a tensile strength, but that it is unnecessary. Both sides were well represented at the recent meeting of the Institution of Naval Architects, and we have already put our readers in possession of the arguments used, but there is much more to be said on this matter than was uttered in the discussion on the papers by Mr. Denny and Mr. West, and we do not apologize to our readers for returning to the subject, and considering what the steel of the future will be.

Let it be supposed that there is no difficulty in producing trustworthy steels, one of which shall have a tensile strength of 28 tons, and the other a tensile strength of 35 tons to the square inch. It is urged that the first is strong enough for all constructive purposes whatever, and that it is even too strong for all work put together with rivets, such as boilers and ships. So far, it has been found impossible to make a riveted seam—in which the rivets shall be of steel as well as the plates—which will have a greater tensile strength than 19 tons on the square inch of section of one plate. The reason why is very suggestive. It lies in the extreme softness of the rivets. All attempts to make rivets of any but the very mildest steel have ended in disappointment. In order, then, to bring up the strength of the riveted seams of a steel

boiler, let us say, it is essential either to use iron rivets, or to so construct the seams that the sectional area of the rivets shall be about 20 per cent. greater than that of one of the two plates riveted together. It will be seen that if this is done incautiously, the plate will be weakened by loss of material, while the rivets are strengthened. It is not impossible, however, by the use of butt straps, to bring up the strength of the seam nearly to that of the plate; but this involves trouble and expense, and it may be taken for granted that no conceivable single riveted seam—steel plates and steel rivets being used—can have more than 19 tons tensile strength per inch of section, while it is more than probable that the resisting powers of such a seam will be very much less. This being so, either the use of steel for boilers is attended with much inconvenience, or else the advantage supposed to result from the use of steel must be, to a certain extent, sacrificed, But on the other hand, it may be taken for granted that boiler seams which will stand 19 tons on the square inch of strain are strong enough for any required pressure. If, then, we can get this strength by using a ductile metal, with a tensile strength of 28 tons on the inch, why should we use a material which is not ductile, and has a tensile strength out of all proportion to that of the seams which can be made with it? We confess that to us the argument seems to be unanswerable; and it is worth notice that when it was urged at the recent meeting of the Institution of Naval Architects no one tried to answer it. There are, however, purposes for which steel may be used when no riveting is required, and it is not impossible that welding may yet take the place of riveting. Nor is it too much to suppose that boiler rings as much as 14 ft. in diameter, 8 ft. or 9 ft. wide, and an inch thick, may yet be rolled as easily as a 7 ft. tire for a locomotive. If riveting can be dispensed with, then all the advantages of a high steel probably can be realized. We may concede this point at once, and we are then immediately face to face with the question, what are the advantages of high steel? In other words, in what constructive sense is a 35 or 40 ton steel better than a 28 or 30 ton steel?

Dr. Siemens is at once a practical steelmaker, and well acquainted with the use of the metal in its various forms; and he has, moreover, made its nature and peculiarities a special study. He has brought to his work, moreover, a well trained mind and no small scientific acquirements. This being the case, whatever he says concerning steel deserves attention. Now Dr. Siemens has stated that which is tantamount to the assertion that high steel has no advantage over low steel; nay, that low steel is the better constructive material of the two, and he bases his statements on the fact that two steels, the one high and the other low—the one a 30 ton and the other a 50 ton steel, let us suppose—will behave precisely the same way up to a strain of 15 tons on the square inch. Here we may point out that it would be imprudent—and will probably be impossible with safety, because of other conditions apart from the strength of steel—to put a greater strain on any structure such as a bridge than 10 tons on the square inch. But this is well within the limit beyond which high and low steel act different parts. If, then, a steel is never to be strained to more than 10 tons on the inch, it seems as though nothing whatever would be gained by adopting high steels instead of low. But there is another element to be considered. Steel with a tensile strength of much over 30 tons cannot be worked up without annealing. If it is punched, or sheared, or bent in any way, it has to go to the annealing furnace; but, as Dr. Siemens has pointed out, the immediate result of annealing is to take away 20 per cent. of the resisting power previously possessed by the material. A 50-ton steel before annealing is a 40-ton steel after the process. But low steels can be worked without any annealing whatever. It certainly seems absurd to make a refractory metal which cannot be used until it has been brought to the condition approaching that of a low steel. The advocates of high steels will have to look this question all over, and provide a satisfactory answer for it, before they can assert with truth that they have made their case good.

Those who support the claims of mild

or low steel urge that its great ductility is all in its favor. We venture to think, however, that the value of ductility *per se* is very much over-rated. If a bar or a plate stretches 20 per cent. before it breaks, the fact supplies useful evidence concerning the nature of the steel; but ductility is itself a quality very seldom needed in structures. For example, it is totally useless in boiler plates, once they are made and put to work; again, in bridges it is never needed, nor in piston rods, railway axles, or crank shafts. It serves a good purpose sometimes, as far as a mere process of manufacture is concerned. Thus it is useful when the plates of a boiler will not come together quite fair, or when a ship's rib has to be bent. But the occasions on which ductility is of service in the life of a structure are very few and far between; possibly they are all confined to ships—which now and then bump on rocks, or, as in the case quoted by Mr. Laird, on hidden obstructions—and to guns, and perhaps armor plates; for ship plates therefore it may be admitted that ductility is of service, but, as we have said, it is of no service at all in boilers, or bridges, or steam engines, or girders; that is to say, that for such structures a metal which would stretch but 5 per cent. before it broke, would be as good as one which stretched 20 per cent., other things being equal, and might be very much better. For example, a boiler of 50 ton steel plates ought to stand without failure nearly twice as much increase of pressure as one of 28 ton steel, and this argument of the non-utility of ductility is really the strongest perhaps that can be urged by those who favor high steel. It is so good an argument that the high steel party would find it worth while to make some experiments to fully demonstrate its truth. Two girders, for example, one of 30 and the other of 50 tons steel, might be constructed, and loaded and unloaded, in a way practiced by Fairbairn many years ago, and two boilers, one of high, and the other of low steel, might be tested in various ways. The benefits which would be gained if only a 50 ton steel could be used are enormous in certain cases. For example, an entirely new era in bridge building would be opened up if a working load of 15 tons on the square inch, or even of 10 tons, might be adopted in lieu of 5 tons. Marine boilers, again—the riveting difficulty being got over—might be made less than half as thick as they are now. At present, however, neither engineers nor shipbuilders are disposed to give up ductility, but until they do, or at least until they greatly modify their demands in this direction, the high steels have no chance of taking a place in the market as a material of construction. Up to the present, no one has succeeded in making for sale a 50-ton steel with 20 per cent. of elongation, and it is by no means improbable that the non-ductility of the metal is essential to its powers of resisting tensile strain. If this be the case, then, the steel of the future must be a mild or low steel, and our own present conviction is that Dr. Siemens is right, and that the efforts of steel makers should be concentrated on the production of a ductile material—in other words, a thoroughly trustworthy 30-ton steel. This will be the steel of the future, unless either of two things can be brought to pass—namely, the abandonment of ductility by the users of steel, or the combination of ductility with a high power of resisting tensile strain by the makers of steel. Neither the one nor the other of these conditions appears to be at all likely to be satisfied for a long time to come. It is well, however, that engineers should consider whether they are or are not too timorous in the use of imperfectly ductile steels for certain structures to the safety of which ductility appears to be in no conceivable way essential.

THE PRESSURE OF WIND.

From "The Architect."

The following evidence was also given at the Tay Bridge Inquiry, in addition to what was printed last week:

Dr. William Pole, C. E., was examined by Mr. Bidder, counsel for Sir Thomas Bouch. Q. Coming now to the question of wind pressure, explain generally what is known in regard to it? Witness pointed that the question had been thoroughly sifted by Mr. Smeaton in 1759, that engineer having adopted a formula which had since been universally recognized among professional men. According to it, a high wind exerted a pressure of from 4.4 to 6 lbs. on the square foot; a very high wind, from 7.8 to 10 lbs.; a storm or tempest, 12.3 lbs., being equal to a velocity of 50 miles an hour. A great storm would exert a pressure of about 17.7 lbs.; a hurricane, 31.49 lbs.; and a hurricane that could uproot trees and carry away buildings, &c.—a phenomenon which would apply to the tropics—49 lbs. Witness proceeded to say that one of the earliest bridges in which iron was employed with large spans was the Britannia Bridge, which was erected in a locality notorious for its violent storms. In the construction of this considerable attention had been given by Mr. Stephenson to the subject of wind pressure, and in this particular he had been assisted by Mr. Edwin Clarke. A quarter of a century ago the latter gentleman reported that during a violent gale then experienced, the tubes were but slightly affected, although one of them was resting at each end on a pile of loose planks at an elevation of about 100 feet. The lateral motion had amounted to about 1½ inches. The blow struck by the gale was not simultaneous throughout the tube, but had impinged locally and at unequal intervals on all parts of the length which presented its broadside to the storm. On that occasion it was said to be impossible to pass along the tube except by clinging to the windward edge. The remark of the Astronomer-Royal the other day regarding the local and partial character of violent gales was curiously corroborated by this case, as to which he did not think that official had any knowledge. At first, Stephenson adopted a high figure for wind pressure—46 lbs. per square foot—but it did not appear that that had been made use of in designing the bridge, the ultimate calculation being that a violent storm would exert a force of 20 lbs. on every square foot of surface exposed to its direct action. Q. I think from the date of that bridge, down to 1873, there is nothing further to be gleaned from literature or experience to throw any further light on wind pressure? A. I know of nothing more until the Forth Bridge came under consideration. Q. According to your experience, what was, up to that time, the ordinary practice? A. The wind pressure was supposed to be covered by the ordinary margin, particularly in girders of an open character? Q. In 1873, when the Forth Bridge project came under consideration, the proposal was considered of a very exceptional character? A. Yes. Several eminent engineers were consulted, and the investigation of the details of the calculations for the design was undertaken by Mr. Barlow and myself, assisted by Mr. Stewart. Q. In discharging your duty I believe it was felt that the question of wind pressure, having regard to the large spans, required careful consideration? A. Yes. It was with the view of arriving at just conclusions upon that point that the Astronomer-Royal was consulted by Mr. Barlow and myself before reporting on the structure. Q. Is there any point in regard to that consultation to which you wish to draw attention? A. No, I may merely say that we did not rely on his report alone. We went to Greenwich Observatory, and had a long conversation, and the Astronomer-Royal laid before us all his records and observations very fully. He explained to us what he afterwards put in writing, and his explanations were so satisfactory that we entirely concurred in his views. Q. Assuming that the Astronomer-Royal's calculation of 10 lbs. wind pressure per square foot for the Forth Bridge was well founded, do you see any reason why

a different figure should have been adopted with regard to the Tay Bridge? It has been suggested, as you are aware, that the Forth Bridge has longer spans than any individual one on the Tay Bridge? A. The only reason why it should be increased in the Tay Bridge is, I should fancy, the smaller dimensions of the spans, and therefore the greater probabililty of the action of gusts of wind upon these spans than upon larger ones. The dimensions of the Tay Bridge spans must be taken as two spans for the purpose of comparison, because unless the wind blew over two spans it would not exert its full force on one span. These two spans would be nearly 500 feet in length as compared with the Forth Bridge spans of 1,600 feet. In respect of that diminution of dimensions, it was considered proper to make some increase in the force to be provided for. Q. Assuming that 10 lbs. is sufficient for a 1,600 feet span, would the increase due to the lessened dimensions in the case of the Tay Bridge be anything like double? A. I do not know. I have no means of forming a calculation. I confess when I heard that 20 lbs. was estimated for the bridge, that I thought it to be ample, judging from my previous data. Q. Your judgment, according to the knowledge and experience obtainable by scientific men at the time that the bridge was designed, was that it was a structure for which a wind pressure of 20 lbs. was amply sufficient? A. I certainly think so, and I think that that was the opinion of engineers generally, so far as I can guess.

Cross-examined by Mr. Trayner: Q. From whom did you get the information that the Tay Bridge was designed to bear a wind pressure of 20 lbs. per square foot? A. From Mr. Stewart. Q. You say that a higher wind than this would be tropical, as it would uproot the trees and throw down houses. Have you never heard of trees being uprooted and houses thrown down in this country by the wind? A. I have heard of the tearing up of trees, but not of the throwing down of houses. Q. You say that no engineer since Smeaton's time has pointed to a higher pressure than 20 lbs. as being necessary to be provided against? A. I do not know of any. Q. Is Professor Rankine not an authority? A. Yes, I recognize him as a mathematical authority. Q. Well he, in 1866, published a book which deals with the maximum wind pressure, and he says, "In Britain that pressure is about 55 lbs. a square foot"? A. He is not an authority upon that, but upon mathematical calculations. Q. Do you think that Professor Rankine, in issuing under the sanction of his name a rule relative to the ascertainment of wind pressure, was likely to put forward a statement which he had not verified in some way for himself, or ascertained the correctness of it? A. I think he is in error in that. Such a pressure would be a whirl of wind that would apply only to a single stick standing up in the air. I do not believe that any one ever considered such a pressure in building a large structure. Q. Do you know Sir William Fairbairn's book on tubular bridges, published in 1849? A. Yes. Q. Writing to Mr. Stephenson, he said: "If we adhere to our original calculations of 50 lbs. to the square foot for the lateral pressure of wind, we find," and so on. Is not that an instance of an engineer making provision for a larger wind pressure than 20 lbs.? A. Mr. Stephenson in his original design took the high pressure of 46 lbs., but at a later period he adopted 20 lbs. Q. What, in your opinion, was the weakest part of the present structure? A. The lowest diagonal tie. Q. If subjected to a pressure of 40 lbs. on the structure, would it be strained considerably beyond the limits of elasticity? A. Yes. Q. If that diagonal tie was exposed to any such strain on more than one or two occasions, would it not do it a permanent injury? A. It would give it a permanent set, but it would not be more liable to fracture. Q. You agreed with the Astronomer-Royal that 10 lbs. was sufficient to provide for in the case of the Forth Bridge, and you deduced from that that 20 lbs. was ample in the case of the Tay Bridge? A. Yes. Q. What were the conditions which made you think it was necessary to provide for a greater lateral pressure in the Tay Bridge than in the Forth? A. The smaller lateral structure of the former. Q. Did you take into account the different sites? A. No. I think the Forth is exposed to quite as violent gusts. Q. Was there anything else in the construction of the two

bridges that would lead you to a different conclusion as to the amount of wind pressure which each was able to resist? A. The different estimates of wind pressure would be provided for in the construction.

Mr. Benjamin Baker, C.E., who was examined by Mr. Bidder, said: Q. Having regard to the wind pressure alone, and what the bridge had to bear on the night of December 28, what is your opinion as to the wind pressure that the bridge as a whole had to bear? A. I do not think the ruling maximum pressure on that night exceeded 15 lbs per square foot. I think the strength of the structure as it now exists would have been destroyed had the wind pressure exceeded that amount. There are two signal-boxes—one at the end of the bridge and another some distance off. Amongst other experiments I made from time to time I tested a great deal of glass up to $1\frac{1}{8}$ inch in thickness. I have tested the strength of a window with the sash-bars in one of the signal-boxes by placing a ledge round and pumping water on to it until the glass broke. Taking these two things together, I got a very simple rule as to the strength of a pane of glass, and applying that information to the windows here, I found that the effective pressure on the door of the signal-box would not exceed 9 lbs. per square foot, and in the other about double that figure. The pane of glass in the door was 2 feet 3 inches in height by 2 feet wide and $\frac{1}{16}$ of an inch thick, and on the windward side of the bridge. In further illustration of his opinion, witness cited the case of the wooden gable of the Caledonian Railway Station, and a photographer's establishment near the bridge, each of which could not have stood more than 15 lbs. wind pressure. He did not think that the wind pressure over a span of girder exceeded 15 lbs. He had looked for evidence, without success, of any structure capable of bearing 20 lbs. per square foot, which had been blown down. Some years ago, when a good deal of discussion took place about the high pressure to which the Cleopatra's Needle would be subjected, he issued a challenge in *The Times* asking for any case in which a structure had been blown down with a wind pressure above 20 lbs., but had never received a single instance, though he had searched for fifteen years. Q. It has been suggested in this case that the wind upon the limited surface of a second-class carriage might have blown it over. Have you ascertained what pressure would blow a carriage over? A. There are three very well known instances of carriages being blown over in France. They are cited over and over again, and they are the basis upon which French engineers proceed in calculating their viaducts. They all occurred in the same district of France, near the Pyrenees. Two instances occurred on February 27, 1860, one near Salse and the other at Rivsaltes, and the third on January 19, 1863, at Lenchee Station. The carriages were empty at the time they were blown over, and the train was running. In the last case a whole train of seventeen carriages was blown over while it was standing on a siding. The French engineers calculated the wind pressure in the same way as Dr. Pole and others. It varied from 24.2 lbs. to 32.5 lbs. per square foot. On the basis of that result, French engineers since that date had always assumed the wind pressure on a train on a viaduct to be 34.5 lbs. per square foot. This practice is universal in France. I have also heard of a horse-box being blown over in India, and also carriages, but that does not afford useful data, but is only another instance of the fact occurring.

Cross-examined by Mr. Trayner: Q. Do you happen to know that Professor Rankine's basis of wind pressure in Great Britain is 55 lbs. per square foot? A. Well, he may say so, but I think it is of no use, because it is not based on experiments. The appliances for measuring wind pressure are very crude and unsatisfactory, and I do not attach any importance to them at all. Q. On what authority do you proceed? A. My own observation. Q. And you do not value any other man's opinions upon which to rely as regards wind tests? A. Certainly not Professor Rankine's. Q. Why do you object to Professor Rankine? A. Because he is not an original observer. Q. The Astronomer Royal, in his evidence, stated that the wind pressure in Scotland would be 50 lbs. per square foot, and alluding to the con-

tracted valley of the Tay, he thought the wind pressure on the night the bridge fell down may have advanced to 100 lbs. per square foot. What do you think of that? A. I think it is pure assumption.

By Mr. Rothery: Q. You say Professor Rankine is not an original observer. Are you? A. Yes; and I could give you a tremendous number of observations of my own in which I have found that structures have failed at 15 lbs. pressure, and frequently at 13 lbs. Q. What allowance is made for wind pressure in England? A. Every engineer differs from another in his mode of allowing for the wind. There is no fixed limit. Q. What allowance do you assume yourself? A. I assume there may be a wind pressure of about 28 lbs. per square foot, and I make that allowance in the construction.

Mr. Balfour said: Now that the Tay Bridge had fallen, everybody declared that enormous pressure of wind should be provided for, and that Sir T. Bouch should have known of this. But General Hutchinson showed that they had no data to go on, and wind pressure over large surfaces was not taken into account.

Mr. Rothery said it might be taken as universally conceded that engineers did not in practice allow for it.

Mr. Bidder said that they must not draw deductions from the disaster. If the Tay Bridge failed from the wind, it showed, no doubt, that wind might destroy such a structure, but they must accept the testimony as to what was held previously: namely, that no wind pressure sufficient to blow down this bridge need be expected. No man could consequently blame Sir Thomas Bouch for having built a bridge insufficient to bear the wind pressure that came upon it, without blaming far more severely General Hutchinson for passing the bridge on the hypothesis that it was sufficient to bear it. But, in fact, neither of them were to blame. They both acted on the knowledge and experience existing at the time. The question of design narrowed itself to the sufficiency of the piers to resist lateral wind pressure. Now, what amount of this were the piers capable of resisting, and what amount was likely to come upon them? They had it in evidence that the designer thought that to provide for 20 lbs. of wind pressure would be sufficient. No more, they were told on all hands, was necessary. Ought Sir Thomas Bouch to have provided for more? What did the previous knowledge of engineers show ought to have been provided for? In the Astronomer-Royal's report of 1873, he said that in regard to a bridge of gigantic character and daring conception, which was to bridge the Forth by two spans of 1,600 feet, a provision to resist a wind pressure of 10 lbs. was sufficient. That report did not mean that the Forth Bridge, with certain peculiar advantages, would only have 10 lbs. per square foot over its extent of surface, but that any plane surface of this extent would have no more than this to meet. The Tay Bridge, whose girders were continuous, was, he (Mr. Bidder) thought, as advantageously placed for resisting a heavy pressure over a limited surface, as was the Forth Bridge. If the Astronomer-Royal led them astray in regard to the Fourth Bridge, this disaster to the Tay Bridge must be also traced back to him. But, in fact, the Astronomer-Royal's view was the general view of the whole engineering world at the time.

THE STRENGTH OF FLAT STAYED SURFACES.

From "The Engineer."

Although the flat sides of fire-boxes to the number of many thousands are in daily use wherever the railway system is found, very few experiments have been made to determine the absolute powers of resistance of, or the best proportion for, flat stayed surfaces. The sides of locomotive fire-boxes have, as a rule, such a large margin of strength that they seldom fail; and it would appear that little or nothing could be gained by altering the present plan of using ¾in. or ⅞in. copper stays screwed and riveted over, and spaced 4 in. apart center to center.

But there are other flat surfaces besides the sides of the fire-boxes of locomotives and portable engines which need staying. Such surfaces are to be found, for example, in marine boilers; and it will be remembered that a great deal was at one time thought to turn on the construction of a flat stayed surface in the exploded boiler of H. M. S. Thunderer. It is by no means clear that we know as much as is desirable about structures in which the stays are spaced further apart than 4in. or 5 in.; indeed, all that was known on the subject until the other day may be expressed in very few words. Stay bolts $\frac{3}{4}$in. in diameter, with enlarged ends—a form which gives the best results—may be depended on to stand the following strains: Copper stays, screwed and riveted into copper, 7 tons; iron into copper, screwed and riveted, will stand 10 tons; iron stays only screwed into copper will bear 8 tons; while iron stays screwed and riveted into iron plates will support 12 tons. In applying these facts in practice we have but to consider how many inches of surface multiplied by the pressure per inch which the boiler will have to bear, will give the permissible strain. For example, the side of a fire-box made up with iron stays $\frac{3}{4}$in. diameter, screwed and riveted into a copper plate may be considered safe with a strain of 2 tons on each stay. If the working pressure be 140 lbs. on the square inch, then each stay may be supposed to support $\frac{4480}{140}=32$ square inches. Such stays might, therefore, be spaced 5.65in., or say $5\frac{1}{2}$in. asunder. If spaced 4in. asunder the strain on each stay will be only one-tenth of that at which it would give way. Experiments made by Fairbairn, however, go to show that the strength of surfaces closely stayed is much greater than may be deduced from the respective areas of the surfaces supported; because, when the stays are far apart, the plate between them bends, though the stays will not give way, and the holes through which the stays pass become distorted, and so the stays slip through. Thus in the experiments to which we have just alluded, it was found that flat surfaces stayed at 5in. apart gave way when the strain on each stay reached 9 tons, while with 4in. spaces, everything else remaining as before, the strength of each stay reach $11\frac{1}{2}$ tons. Stay bolts spaced far asunder, as in marine boiler work, give somewhat different results. Within reasonable limits the power of resistance of $1\frac{1}{4}$in. stays screwed and riveted into iron plate, varies as the square of the thickness of the plates, the yielding point being reached with $\frac{7}{16}$ in. plates at $11\frac{1}{4}$ tons, and with $\frac{1}{2}$in. plates at $14\frac{3}{4}$ tons. Mr. D. K. Clark gives a rule laid down by Mr. W. Bury for finding the working pressure in marine boilers, which is to the effect that 112 times the square of the thickness of the plate in sixteenths of an inch, divided by the area of stayed surface in square inches per stay, equals the working pressure.

The United States Government, dissatisfied with the meager amount of information existing on this subject, the gist of which we have just given, gave instructions last year to Messrs. Sprague and Tower, naval engineers, to carry out a series of "experiments to determine the value and resistance of screw stay bolts for boilers under different conditions, using iron, steel, and copper of different thicknesses." We have already referred to the report prepared in accordance with this order as being imperfect. "Want of time prevents the discussion of the matter as fully as desirable," write Messrs. Sprague and Tower; but want of time did not prevent them from preparing a multitude of tables of results, and we much regret that they did not—time being it appears of importance—cut their experiments short, and discuss their results as they ought to be discussed. The report appears in the form of an appendix to the last "Annual Report of the Chief of the Bureau of Steam Engineering for 1879." The apparatus used consisted of a ring of gun-metal, 4in. deep and 18in. internal, and 23in. external diameter, faced on both sides, and provided with thirty-one holes, through which bolts passed to secure the plates to be tested. All the experimental plates were cut to the outer diameter of the ring, made quite flat, and the stay bolt holes drilled. The stay bolts, after the first few experiments, were all secured by inside and outside nuts in a thick back plate. The thin front plate was the experimental plate. The results obtained may, to a certain extent, be

summarized; they cannot be completely and properly dealt with by any one but Messrs. Sprague and Tower. 1in. bolts not riveted, but only screwed into $\frac{1}{2}$in. iron plates, were pulled through the plate with a strain of 9.3 tons; 1in. bolts riveted with an ordinary low conical head, three threads being left for riveting, drew with a strain of 11 tons; 1in. bolts with a button head rivet made with a snap, a length of bolt equal to seven-sixteenths of its diameter being left for riveting, stood 15.1 tons before giving way; while a $1\frac{1}{4}$in. bolt, snap riveted, a length of bolt equal to half its diameter being left for the purpose, stood 17.3 tons. All these stays were spaced 4in. from center to center. When the distance was augmented to 5in., other things remaining the same, the strains supported were 9.8 tons, 14 tons, and 15.5 tons. If we compare these figures, it will be seen that the form and dimensions of the rivet head exercise a most important influence, good shape and size augmenting the strength of each stay from 9.3 tons for an unriveted stay to as much as 15.1 tons for stays properly riveted. No experiments made in this country have served to demonstrate this important circumstance. If, again, we compare the figures we have given with those obtained by Fairbairn, we shall find some points worthy of note. The best result obtained by Fairbairn was with $\frac{3}{4}$in. stays, screwed and riveted into a $\frac{3}{8}$in. plate. These bore a strain of 12.5 tons before failure. The sectional area of such a stay is .4417 square inch, while that of a 1in. stay is .7854in. If the power of resistance of the stays varied as their sections, then a 1in. stay should have stood over 22 tons; but as this contemplates a tensile strength in the iron of which the stay was made of over 28 tons on the square inch, it is tolerably clear that under the conditions the stay would have snapped before it pulled through the plate. We may compare the American experiments with those made by Mr. Phillips in Plymouth Dockyard, when $1\frac{3}{8}$in. bolts in $\frac{1}{2}$in. plates stood but 14.73 tons—say 15 tons. But the sectional area of these bolts was to that of the American bolts as 1.448 is to .7854, or very nearly two to one. From this it appears that nothing is to be gained by augmenting the diameter of a stay bolt unless the thickness of the plate is augmented at the same time; and it may be taken for granted that a stay bolt whose diameter is twice as great as the thickness of the plate is as thick as it can be made with advantage, probably a little thicker. We are now dealing, of course, with comparatively thin plates. Concerning the strength of stayed surfaces of plates $\frac{3}{4}$in. thick or upwards, nothing is thoroughly known.

The experiments of Messrs. Sprague and Tower were fortunately extended to steel. We have not space to give particulars of the tests. It must suffice to say that in comparing the results of three different thicknesses, in each case —$\frac{1}{4}$in., $\frac{3}{8}$in., $\frac{1}{2}$in. plate—of iron plates and iron bolts, steel plates and iron bolts, steel plates and steel bolts, the diameter of the bolts being 1in., $1\frac{1}{8}$in., and $1\frac{1}{4}$in., their distance apart and conditions of trial being the same, it wa found that in the case of the iron plates and iron bolts the strain required to draw the bolts through the plates was equal to 74.77 per cent. of the tensile strength of the bolt; with the steel plates and iron bolts 77.36 per cent.; and with the steel plates and steel bolts 85.44 per cent. The tensile strength of the Otis steel stay bolts was but little over 19 tons on the square inch, or as nearly as possible that of the iron bolts used; and the steel was as soft as Lowmoor iron, to judge from the statements made concerning the ease with which it was riveted. We have no information concerning the strength of the Otis plates, but we may take it for granted that they closely resembled the bolts. In nearly if not all cases the failure of the steel bolts began with the splitting of the rivet heads of some of the central stays; and it is extremely probable that if a harder steel had been used the resistance of the stays would have been much increased. We may remark before concluding that information is much needed concerning the behavior of steel stayed structures. Experiments in this direction cannot be much longer postponed. They need not be elaborate, nor very costly, and the ground being to all intents and purposes untrodden, any practical engineer with sufficient time at his disposal could obtain a great deal of valuable information. This is a line of

experiment which we commend to the Research Committee of the Institution of Mechanical Engineers. It is to be hoped that the United States Government, which deserves no small thanks, first for carrying out useful practical inquiries, and then giving the results to the world, may see fit to extend the investigations of Messrs. Sprague and Tower, who appear to be highly competent men, to steel such as we are accustomed to use in this country. The Otis, so-called "steel" appears to be more a peculiarly fine and homogeneous iron than anything else. It certainly would hardly be regarded as a steel in England.

Dr. Siemens' Newest Electrical Results.—A paper was read on Thursday night before a crowded meeting of the Society of Telegraphic Engineers by Dr. Siemens, F. R. S., upon "Recent Applications of the Dynamo-Electric Current to Metallurgy, Horticulture and the Transmission of Power." The President, Mr. W. H. Preece, was in the chair. In his paper Dr. Siemens said that he was prepared to corroborate a statement which he had made on a previous occasion, affirming the applicability of the dynamo-electric current to hitherto unaccustomed purposes. Among these purposes was the transmission of power, and the accomplishment of large chemical results, such as the decomposition of metallic salts. The electric arc was capable of producing intense heat with a moderate expenditure of energy, and of effecting the fusion of platinum or steel. Amidst loud applause, Dr. Siemens personally illustrated this by the experiment of melting two quantities of steel in a plumbago crucible, the first being fused within a quarter of an hour, and the second within the short space of eight minutes. In describing the effect of the electric arc upon horticulture, Dr. Siemens related the result of some experiments he had made in this direction. They went to prove that the electric light was efficacious in ripening fruit, and if this should be confirmed, the horticulturist would become independent of solar light in producing a high quality of fruit at all seasons of the year. With regard to the application of the dynamo-electric current to mechanical propulsion, Dr. Siemens gave details of a practical trial which had been made in Berlin of a toy railway upon this system.

REPORTS OF ENGINEERING SOCIETIES.

Society of Engineers.—At a meeting of the Society of Engineers, held on Monday evening, June 7th, in the Society's Hall, Victoria Street, Westminster, Mr. Joseph Bernays, President, in the chair, a paper was read by Mr. Arthur Rigg, engineer, of 1 Fenchurch Street, London, E. C, on "Sensitiveness and Isochronism in Governors." As the attainment of a regular rate of speed is the only object of a governor, it is an interesting inquiry how far this result is achieved by the sensitive and isochronous governors, now frequently applied to steam engines. The irregular manner in which power is communicated from a piston to a crank causes periodical variations in speed, which vary greatly in their degree, between such classes of steam engine as the common agricultural type and the high class mill engine. Whenever there is great sensitiveness in a governor, it is often found that inherent irregularities in speed tell to such an extent that the governor becomes uncertain, runs from one extreme of its range to another, and produces hopeless confusion in the speed of the engine it was intended to regulate—giving, in fact, a worse result, than would be produced by a governor of the common type. This evil has been remedied by retarding the movement of sensitive governors, causing their movement to force fluids through small orifices, an unreliable method now superseded by a method invented by the author, whereby the balls overcome the inertia of a mass of metal as they move in or out, a plan applicable to the usual type of governors, and also to those which are direct-acting, fixed upon an engine shaft and altering the stroke of an expansion eccentric. Thus, such governors may be made to effect a more uniform regulation than has hitherto been attainable, and their extreme simplicity remains without attendant disadvantages. An illustration of the relay system was given, where the governor moves a valve, admitting hydraulic pressure under a plunger to raise or lower the sluice of a turbine, and so regulate its rate of motion. It was finally shown that governor and engine should correspond in their relations so as to work harmoniously together; and that perfect regularity is unattainable, and can only be approached by providing sufficient inertia in the moving parts to diminish the effect of irregularities in power or resistance until the governor can operate; and that a high rate of revolution attains this condition with the greatest economy and success; and that although the governor may advantageously approach isochronism, its sensitiveness must not be excessive.

IRON AND STEL NOTES.

Report on the Results Obtained by Testing Steel Rails at Natural and Artificially Lowered Temperatures.—One of the most important questions under con-

sideration in elaborating the technical conditions for steel rails ordered by the Russian Government from native works, with the view of creating in Russia the manufacture of rails, was the following: How to ensure a hard rail—*i. e.*, containing a high percentage of carbon and phosphorus—which will stand the test in the summer at a warm temperature, without being too brittle for wear in the cold winter time, and whether, by freezing, those rails should stand the same tests as when tested at a warm temperature. With the view of obtaining some guarantee in this respect, it was proposed, firstly, to increase the severity of the tests during the summer time; secondly, to prescribe certain limited percentages of carbon and phosphorus in the steel; thirdly, to manufacture rail steel with determined materials, in accordance with samples adopted by the Ministry. These conditions were, however, each of them difficult to carry out in practice, and could only be controlled with difficulty. It then occurred to the director of the Railway Department, Mr. D. J. Jouraffsky, that the desired object might be attained by placing the rail in the summer-time under the same conditions as in the winter, viz., to test the rails in the summer at artificially lowered temperatures. Trials made immediately, in accordance with this idea, proved that the plan could be very easily worked out, and by very cheap and simple means. It was found that by placing pieces of rail 6ft. to 8ft. long in a mixture of ice and salt, the temperature of the rail could be lowered in a very short space of time, during warm weather, to 20 deg. below freezing point Celsius. In order to work out this question to the fullest extent, a special commission, composed of the following engineers, viz, Messrs. Erakoff, Beck, Guerhard, Nicolai, and Feodossieff, was appointed to carry out a series of tests on this plan with rails from different works. The commission fulfilled its task in the following manner: From seven works, viz., those of Cammell & Co., John Brown & Co., Brown, Bailey and Dixon, Creusot, Cockerill, Terre Noire, Pontiloff, and Baird—the latter two Russian works—pieces of rail six ft. long were taken, one of which was tested at the natural temperature, the others being placed in a box filled with a mixture of two parts of small ice and one part of salt, and, after arriving at a temperature of from 16 deg. to 21 deg., which occurred in half an hour, they were submitted to the same tests as the first piece. Small test bars were taken from the same rails to try the tensile strength, and filings were also taken for analysis. The results obtained from all the trials were given in a table, which, for the reasons given below, we do not reproduce, and they have confirmed the idea that the brittleness of the steel increases very much at low temperatures, if it contains more than a certain limit of phosphorus, silicon, and carbon. By examining the tables of the trials, in which the eighty-six samples are divided into two groups, viz., (*a*) rails which broke under the tests, and (*b*) rails which stood the test, we arrive at the following facts: The total of the three elements named in the rails which broke under the test averages 0.54 per cent., and in those which stood the same test 0.41 per cent.; the first total—0.54 per cent.—varying from 0.44 to 0.67 per cent., and the second total—0.41 per cent.—varying from 0.37 to 0.55 per cent. But it is ascertained that the three elements, carbon, phosphorus, and silicon, have not the same influence upon the hardness of the steel. Phosphorus is supposed to have the greatest influence, then silicon, and lastly carbon. The total of the three hardening elements expressed in Dudley's phosphorus units were, for rails which stood the test, 19 units; for rails which broke under the same test, 31 units. In the first the units vary from 16 to 22 in one case only 25 being reached; and in the second the difference was from 22—and that only in two cases, all the others being higher—to 45 units. —*Engineer*.

NITROGEN IN STEEL.—As regards the presence of nitrogen in ingots of pig iron and steel—often in very notable quantity—I will venture upon the following explanation. When an ingot of liquid steel solidifies, it passes from the density of about 6.60 to that of 7.90. A pocket or cavity (*poche de retassement*) is formed, the metal of which has gone to feed other parts of the solid, and during the solidification, no matter what care may be taken to cover in the ingot; as the metal is pervious to gas the air finds its way into the cavity, oxygen is absorbed by the iron, and the reddish color of the walls of the cavity, which are often crystalline, is, in fact, due to oxidation; the nitrogen meanwhile remains imprisoned. It is thus that in some bars of rolled steel it has been proved that ammonia was given off abundantly from a certain point in the bar, probably corresponding with the previously mentioned cavity of the original ingot. There is nothing anomalous in the idea that nitrogen and hydrogen under pressure should combine to form ammonia. This question of the presence of ammonia in steels has been solved, either affirmatively or negatively, by a great many impartial observers.

It is quite permissible to believe that those persons who deny the presence of this gas failed to discover any in the bars of steel on which they operated, and, on the other hand, that those who affirm it really detected its presence. It may, therefore, be supposed that ammonia occurs more especially in steels high in manganese, which have the property of dissolving hydrogen gas, and of absorbing it even at a cherry red heat (800° Cent.), and that it exists, not uniformly distributed, but localized in certain parts of the test bar. Soft steels, with 0.1 per cent. to 0.2 per cent. of manganese, or hard steels high in carbon, would give off little or no ammonia. The explanation I have hazarded is only applicable to determinations of large quantities of nitrogen made on cast ingots of pig metal or steel; but not on isolated bars of small dimensions. Nitrogen, in fact, present in all steels and in all pig irons, only occurs in very small proportion of the total gases therein contained, as was demonstrated by M. Boussingault and Colonel Caron in their discussion with M. Frémy some twenty years

ago.—*M. Pourcel's paper before the Société de l'Industrie Minérale.*

THE difficulty of rendering small steel and iron articles bright, by removing the "scale," or coating of oxide, may—the *Electro-Metallurgist* says—be readily overcome by the following process, without having recourse to the ordinary method of scouring, after pickling with dilute sulphuric acid. First, let the articles be plunged into a boiling solution of caustic potash or soda for a few minutes, to remove greasy matter, then rinse in clean water. Now place the articles in a weak pickle of sulphuric acid—about half a pound of acid to each gallon of water. From ten to twenty minutes' immersion is generally sufficient to loosen the scale or oxide. If the scale be sufficiently loosened, it will readily yield to the touch of the finger. Let the articles be again rinsed, and afterwards dipped, by means of a perforated stoneware basket, into a strong solution of commercial nitric acid for an instant, when the black scale will be immediately removed. The dipping basket should have a rotary motion given to it while in the acid, and then removed promptly and plunged into cold water. The articles may then be coppered, silvered or gilt with ease.

LARGE STEEL PRODUCT.—The Scranton Steel Works made in twenty-four hours, Wednesday, December 10, 466 tons 12 cwt. of ingots. The steel works also made last week their largest week's work to date, 2,415 tons 7 cwt. of ingots, beating their largest previous work by 62 tons.

The steel-rail mill rolled last Wednesday 736 bars in ten hours fifty minutes; average time per bar, fifty-three seconds ; and Wednesday night 800 bars in eleven hours ten minutes ; average time per bar, fifty and a half seconds—a total of 1,536 bars in twenty-two hours, which, it is claimed, has never yet been beaten on any rail train in the world. The largest previous recorded output was 1,044 bars in twenty-four hours, made at Harrisburg in 1877.

The rail mill also rolled last week 1,877 tons 15 cwt. of rails ; this being the largest week's work ever yet recorded on any one rail train, either in Europe or America. Largest previous work was at Harrisburg—1,617 tons, in November, 1877. We will also call the attention of our Lehigh friends to the fact that No. 1 Furnace of the Lackawanna Iron and Coal Company has, during the last fourteen weeks, made the extraordinary average of 544 tons weekly, and their Franklin Furnace, during the same time, 478½ tons weekly.—*Scranton (Pa.) Republican.*

RAILWAY NOTES

ITALIAN TRAMWAYS.—Tramways have now been established in twenty-four cities and towns in Italy, the aggregate length of the lines at the end of 1879 being 320 miles, of which no less than 219 miles are worked by mechanical power, the remaining 101 miles employing horse traction. In addition to the lines already at work there were at the end of last year 89½ miles in course of construction, and no less than 626 miles projected, it being intended that 611½ miles of these projected lines should be worked by steam power or other mechanical means. Altogether steam-worked tram lines for suburban traffic are coming decidedly into power in Italy.

THE railway at Vesuvius was opened this week. The line is 860 metres in length, and from the station at the summit a winding path leads to the edge of the crater. The *Times* correspondent writes : "It is not a train in which one travels, but a single carriage, carrying ten persons only, and as the ascending carriage starts another, counterbalancing it, comes down from the summit, the weight of each being five tons. The carriages are so constructed that, rising or descending, the passenger sits on a level plane, and whatever emotion or hesitation may be felt on starting, changes, before one has risen 20 metres, into a feeling of perfect security."

AT a recent meeting of the Franklin Institute, Mr. W. Barnet Le Van read a paper on "High Railway Speeds," suggested by the trial trip of the locomotive built at the Baldwin Locomotive Works for the Reading Railroad Company, and intended to run from Philadelphia to New York in 90 minutes, or at the rate of a mile minute. To do this it must be capable of running at a faster rate on parts of the road to make up for time lost in passing over bridges and through towns, where a slower rate is necessary. To accomplish this with safety the road bed must be in perfect condition, and some changes must be made in the form of locomotives as now commonly used. This new locomotive has a single pair of driving wheels 6½ feet in diameter, in place of coupled drivers of 5½ feet in diameter. In the latter form of engines run at high speed there is danger that the coupling rods connecting the driving wheels will be broken by centrifugal force. The larger wheel also reduces the number of revolutions per mile of run. In the new locomotive the boiler has 1400 square feet of heating surface and about 56 square feet of grate surface. The dimensions are as follows : Diameter of cylinder, 18 inches ; length of stroke, 24 inches; diameter of driving wheel, 78 inches ; wheel base, 21 feet 1 inch; distance from centre of driving wheel to centre of trailing wheel, 8 feet. The boiler is made of $\frac{7}{16}$ inch steel and is 52 inches in diameter. It contains 198 tubes 2 inches in diameter and 12 feet 2¾ inches long. The fire box is 96½ by 84 inches. The capacity of the tender is about 3,800 gallons of water, and weight when filled with water and coal, 70,000 pounds. The weight of the engine is 85,000 lbs., and is so disposed that by an alteration of fulcrum points additional weight can be thrown on the drivers at the time of starting. At a trial trip on May 14th, the engine was attached to a train of four cars, each weighing about 42,000 pounds, making the weight of the train complete, about 148 tons. The run was made at rates ranging from 27 miles an hour, between Ninth and Green and Wayne stations, to 62 miles an hour, between Trenton Junction and Bound Brook, the time from Ninth and

Green to Jersey City (89.4 miles) being 98 minutes, or at the rate of 54¾ miles per hour. On the return trip the run was made in 100 minutes. In a former trip the engine developed a speed of nearly seventy-nine miles an hour. In these trial trips the engine consumed 36 gallons or 300 pounds of water per minute. Mr. Le Van prophesied that within five years "passengers would be set down in New York in New York in one hour's time from this city." The average time on English railways is 46 miles per hour, on French 37½, on German 40, and on American 37. On English railways, 6½ feet driving wheels are quite as common as 5½ wheels, and some of the fast lines have 8 and 9 feet wheels, one line having 10 feet wheels. Engines with one pair of drivers are not new in this country, and Mr. Le Van described several which had been built at the Baldwin Locomotive Works, by Edward S. Norris and Norris Brothers, and by Ross Winans, of Baltimore. Some of these developed high rates of speed.

The number of passengers killed in accidents on the railways of Prussia in 1878 was twelve, while forty-six was the number of the injured. The cause in eight of the fatal and sixteen of the non-fatal cases was imprudence or want of caution on the part of the victims or sufferers themselves in entering or alighting from the carriages. The deaths were only one in every 9½ million passengers, and the cases of injury only one in every 2½ million passengers. This result shows an improvement in regard to the safety of traveling on Prussian lines. The average of five normal years before the last showed that there had been one passenger in every 5¾ millions killed, and one injured in every 1¼ million passengers. Of the railway servants and officials there was an accident last year to one in every 171, while among the railway laborers there was an accident to one in every 120. There were ninety-three persons who attempted suicide by laying themselves on the line, and eighty-six of these cases were attended with fatal results.

Railway Statistics.—Since 1875, some 10,268 miles have been built in Europe, and about 5,000 miles in other parts of the world outside of the United States, chiefly in Australia and India, so that the world's railways probably stand to-day as follows :

Europe	98,275 miles, or	47 per cent.	
United States....	86,121	"	41 "
Rest of the world	25,000	"	12 "
	209,396		

Thus our 50 millions of inhabitants have furnished themselves with 86.000 miles of railway, while the 306 millions of Europe have 98,000 miles, and the 1,050 millions of the rest of the world possess but 25,000 miles.

There was in Great Britain on the 1st of January, 1879, 17,333 miles of railway, on which there were about 32,000 miles of track, 12,969 locomotives, 418,322 passenger and freight cars, owned by the companies, in addition to some owned by private parties, and over which trains ran 222,376,114 miles, and conveyed 565,000,000 passengers.

The capital account of the English roads was 698,545,154 pounds sterling, or $ 3,380,958,545, thus giving an average cost of $195,059 per mile of road.

The average cost per mile in several other countries about the year 1875, was as follows :

France	1873	$152,500
Belgium........	1873	111,342
Germany	1875	100,570
Austria-Hungary	1875	105,847
All Europe.....	1875	120,960
United States...	1879	58,915

Thus our railroads have cost less than half as much per mile as those of Europe.

Going back one year, for purposes of comparison, on the 1st day of January, 1879, we had in the United States, 81,841 miles of railroad, on which there were 101,660 miles of track, or enough to encircle the globe three and a half times. There ran upon these roads 16,445 locomotives, 11,683 passenger cars, 4,413 baggage, mail and express cars, and 423,013 freight cars.

The capital invested was $4,772,297,349, or $58,915 per mile of railroad ; the gross earnings were $490,103,351, or $6,200.52 per mile ; the working expenses were 61.79 per cent. of earnings, or $302,528,184—say $3,887.10 per mile of railroad ; and the net earnings were $187,575,167—say $2,322.42 per mile, or 3.932 per cent. on the nominal capital.

While the greater cheapness of our American railroads is in some measure due to the comparative smoothness of much of our country, and to the absence of heavy land damages, much more is due to the methods of construction applied to the railroads themselves, to the cheap and efficient expedients which our engineers have introduced, and especially to the character of the rolling stock which we have adopted.

The early locomotives obtained an adhesion and tractile power equal to $\frac{1}{14}$ of the weight upon their driving wheels. I believe that in other countries $\frac{1}{7}$ of the weight is even now considered a standard and satisfactory performance, while our American locomotives, including the latest type, the "Consolidation" engine, of 50 tons weight, regularly work up to $\frac{1}{5}$ in winter, and $\frac{1}{4.5}$ in summer, of the weight upon their drivers, with occasional performance up to $\frac{1}{3}$, and even less.

That is to say, if a locomotive has 88,000 pounds weight upon eight driving wheels, and obtains an adhesion of $\frac{1}{7}$, it will pull a train equal in resistance to the lifting of a weight of 12,571 pounds ; while if it works up to $\frac{1}{4.5}$ in adhesion, it would pull 19,555 pounds, or 55 per cent. more under the same circumstances.

Not only do our locomotives pull greater trains than do European locomotives, in proportion to their own weight, but they run more miles in the course of the year ; Stürmer's statistics for 1875, showing that the average train mileage for locomotives (not the engine mileage, but the mileage of passenger and freight trains, divided by the whole number

of locomotives), was for all Europe, 15,720 miles per year, and for the United States, 21,900 miles per annum.

This has been accomplished by a series of improvements in construction, which have brought our locomotives materially to differ from their European prototypes, and which fairly entitle us to speak of them as American in design.—[*Abstract of Mr. Chanute's address at the Convention in St. Louis.*

A TABLE constructed by Professor Stürmer, of Bromberg, shows the length of railway in several of the chief countries of the world, and its proportion to the population. In Europe, on the average, there are 4.9 kilometers of railway to every 10,000 inhabitants. Greece has the least proportion to the population, having only 0.08 kilometer to every 10,000 of the population. Next comes Turkey, with 1.6; Portugal, 2.3; Roumania, 2.4; Russia, 2.8; Italy, 2.9; and so upward in the scale, France having 6.3; Germany, 7.1; Great Britain, 8.1; and Sweden heading the list with 10.8, though its total mileage is not a fifth of that of Great Britain. In Asia it appears that only 0.16 kilometer is averaged to every 10,000 inhabitants; and in Africa the proportion is only 0.17. In the United States the proportion is heavy—32.9 to every 10,000 of the people; while the whole of America has the average of 17.2, and in Australia the proportion is already 10.6.

ENGINEERING STRUCTURES.

THE HUDSON TUNNEL.—This work is already well under way. Beginning in Jersey City, a shaft at the foot of Fifteenth St. has been sunk to the depth of sixty feet. From the foot of this shaft, which is provided with an air-lock, the tunnel is being worked towards the river. The exterior structure or shell of the tunnel consists of a cylinder of one-half inch boiler-plate iron, with a lining of brick two feet thick securely anchored to it. The river on the line of the tunnel is about 5,500 feet in width, and its bed is largely composed of blue clay, with a mixture of sand and other substances.

The excavation is begun at the top, and carried forward in sections. The plates of which the iron casing is composed are placed in position as fast as sufficient space is excavated. These plates are two and one-half feet in width by three and six feet in length. They are bolted together by means of angle-iron secured to their edges. The brick-work is laid as rapidly as a circle of sections is completed. The silt is thrown back into a pool, into which is running a stream of water forced in from a pump in the shaft by the pressure of the condensed air in the tunnel. This water, carrying about one-half of the silt, is blown out through a six inch pipe into the receiving tank. The remaining portion is carried into the finished tunnel.

The office is connected with the tunnel by telephone, and the electric light is used both in and out of the tunnel, work being carried on throughout the 24 hours. An average of about 4 feet of the tunnel is finished daily.

The top of the tunnel will have an average distance of about twenty five feet below the river bed. This makes necessary a considerable grade, as the river at some points reaches the depth of 60 feet.

The entrance to the tunnel on the New Jersey side will be at a point about three-quarters of a mile from the river. The terminus in New York has not been settled, but the tunnel will enter the city at the foot of Leroy St. An underground depot will be used, and nowhere will the track be less than fifteen feet below the surface. The approaches on either side will be 26 feet in width and 24 feet in height, with a double track; but under the river there will be two tunnels, side by side, each 18 feet in height and 16 feet in width, and each containing a single track. Work is now in progress in only one of these tunnels, but everything is in readiness to begin the adjoining one soon, when operations can be begun on the New York side also. With approved facilities it is expected that each section will be advanced at a rate of five feet per day.

WATER SUPPLY OF ADELAIDE (S. A.)—The total quantity of water supplied to Adelaide, South Australia, from the Hope Valley and Thornton Park reservoirs during January was 81,000,000 gallons. The average daily consumption was, therefore, 2,600,000 gallons. The consumption of water varied very much on different days, the variation being partly, but not wholly, due to fluctuations of temperature. It is curious to note that in each week the greatest consumption of water took place on either Tuesday or Wednesday, whilst Friday or Saturday generally were the days on which the demand was the least. The greatest consumption on any one day during the past summer took place on Tuesday, January 13, when 5,120,000 gallons were used; on Wednesday, January 21, there were used 4,070,000 gallons; and on Wednesday, January 28, 4,370,000 gallons. A large amount of work has been lately done by the South Australian Water Works Department, in laying new mains, and but for the activity thus displayed it would have been impossible to maintain the supply of the whole area as effectively as has been done. An idea of the magnitude of the system can be gathered from the fact that the Adelaide water area now comprises 100 square miles of country.—*Engineering.*

DURING the past week the first practical steps have been taken towards realizing another gigantic work of Alpine railway engineering, namely, the Arlberg Railway tunnel. The project will occupy several years in executing, and when complete will worthily rank with the tunnels already in existence through Mount Cenis and the St. Gothard. The work just commenced will open direct railway communication between Austria and Switzerland, and thus provide a direct route between Austria and France without passing, as has hitherto been necessary, through the States of Southern Germany. The operations of the engineers and surveyors during the past few days have been directed mainly towards finally determining the axis of the new tunnel.

The Channel Tunnel.—According to the *France*, the preliminary workings for the tunnel uniting England and France have had the most satisfactory results. The promoters have sunk their shaft to the stratum in which they propose to bore the tunnel, and are now going to sink another shaft and lower all the machinery for the bore. In eighteen months they expect to have reached two kilometers under the Channel, and in three or four years to have completed the task.

The proposed canal from Bordeaux to Narbonne has been reported on by M. Lepinay, and is not unlikely to be carried out. It will be about 250 miles long, the locks allowing the passage of vessels over 400 feet in length. The surface breadth in the narrowest parts will be 184 feet, but for forty-five per cent. of the whole length the canal will be double and 262 feet wide. It is calculated that ordinary cargo steamers will save four days in the voyage from Brest to Malta.

Work on the new Eddystone Lighthouse is progressing rapidly. Two-thirds of the solid base is now brought up to within three feet of high water spring tide, and by the end of the week the rock base will be entirely covered with the stepped courses of masonry. By the end of the season the work will be far less dependent on the weather.

BOOK NOTICES.

Publications Received.

Monthly Report of the Weather Bureau for June.

Minutes of Proceedings of The Institution of Civil Engineers:

"Fixed and Movable Weirs." By Leveson Francis Vernon Harcourt, M. A.; also "Movable Dams in Indian Weirs." By Robt. Burton Buckley, A. M. I. C. E.

Annual Report upon the Survey of Northern and Northwestern Lakes and the Mississippi River. In charge of C. B. Comstock, Major of Engineers, and Brevet Brigadier General U. S. A., Washington Government Printing Office.

Sewers and Drains for Populous Districts By Julius W. Adams, Chief Engineer of the Board of City Works, and Consulting Engineer to the Board of Health, Brooklyn. New York: D Van Nostrand. London: Trübner & Co, Ludgate Hill. Price, $2.50.

The whole question of sewerage for towns has been ably and exhaustively discussed by Mr. Adams, in a volume bearing the above title, and as the London main drainage system has been taken as the basis of the work, it will be quite as acceptable to the sanitary engineers of this country as to those of the United States. In 1857 Mr. Adams was charged with the preparation of plans for the sewering of the City of Brooklyn, covering an area of 20 square miles, much of which was then suburban territory. At that date no gaugings had ever been made of the discharge of sewers, and the only principle recognized was to make the sewers large enough to admit a workman to clean them by the use of shovel and pick. In 1852 the General Board of Health under the Public Health Act made their first report to the British Parliament, and advocated very strongly the introduction of smaller pipes in lieu of the large brick and stone drains heretofore in use for house drainage. The tables appended to the report, however, suggested the use of pipes, which experience proved to be unquestionably too small, so that they became less and less recognized as a standard, until some seven years since they were to some extent replaced by the suggestions of a private English engineer, whose views have in their turn been proved to be quite as erroneous in the other direction. The principle laid down in the Hydraulic Tables of Neville, which is, no doubt, the correct one, has been generally overlooked, and the value of Mr. Adams's book is much enhanced by the fact that it embodies the principle and practice of sewering towns as illustrated in the working of the Brooklyn system, which is based upon the recognition of Neville's principle.

In devising a system of sewerage for a populous district there are, as Mr. Adams points out, several controlling circumstances to be taken into consideration. It would appear at first sight that the first thing to be considered would be the population of the locality. Were the sewers to be confined to the withdrawal of sewage proper from the vicinity of dwellings this would, to a great extent, be the case, but even then the extent of water supply would be a preponderating element in the calculation. If, for instance, the water supply were derived from wells on or near the premises, as in country villages, the amount of sewage would be materially reduced from what might be anticipated were the water for domestic use obtained by the simple act of turning a faucet, and whether the supply of water was intermittent or constant would exercise an important influence on the amount of consumption or waste from dwellings The sewage from a dwelling differs by an insignificant amount in bulk from the water consumed or wasted. In fact, the water taken into a dwelling for all purposes is the measure of the sewage which leaves it; and a generous water supply, such as is found in most cities supplied by waterworks, would, under proper management, suffice to carry off all excrementitious, or human refuse. But with the sewers confined to this purpose an additional system of drains on a grander scale is called for to remove the storm water which would otherwise flood the premises, and prove the cause not only of present injury and discomfort to the inhabitants, but subsequently objectionable as well on sanitary grounds.

The subject is systematically divided, so that the several points demanding attention may be dealt with separately. The question of area and physical outlines and controlling features of the district to be drained, its geological character, and the depth to which it may be desirable that drainage should extend are firs

considered; then that of the rainfall in the district, with consideration of the maximum fall of rain in a given interval of time, and the proportion of such storm water as it is proposed to carry off by the sewers; next the character and extent of the water supply; and, lastly, the final disposal of the sewage. The volume is amply illustrated throughout, and will prove an invaluable work of reference to sanitary engineers wherever the English language is understood.—*Mining Journal.*

ENGINEERING GEOLOGY. By W. HENRY PENNING, F G. S. London: Bailliere, Tindall & Cox. For sale by D. Van Nostrand. Price, $1.40.

How to make a geological survey a part of any preliminary survey for engineering work is the subject of this little treatise. Of course, a previous knowledge of descriptive and dynamic geology is indispensable. To render such knowledge practically useful to the engineer so that he can intelligently and systematically record the geological phenomena of any given district is the aim of the author.

Part I. treats of "Geological Strata, their Nature and Relations, and their Bearing upon Practical Works." Part II. deals with "Procedure in the Field." Part III. is devoted to "Economics, Materials, Minerals and Metals; Springs and Water Supply."

The illustrations though not very abundant are exceedingly good.

AN ELEMENTARY TEXT-BOOK OF BOTANY. Translated from the German of DR. K. PRANTL. The Translations revised by S. H. VINES, M. A., F. L. S. Philadelphia: J. B. Lippincott & Co. For sale by D. Van Nostrand. Price, $2.25.

This book seems adapted to hold an intermediate place among our American text books on Botany, being less rudimentary than some in extensive use, and more elementary than the larger works of Wood and Gray.

It is well illustrated and well printed.

WATER ANALYSIS FOR SANITARY PURPOSES, WITH HINTS FOR THE INTERPRETATION OF RESULTS By E. FRANKLAND, F. R. S. London: John Van Voorst. For sale by D. Van Nostrand. Price, $1.00.

This is probably the most compact of all the authoritative guides to the analyst. It presents in a small compass all the reliable processes for the detection of foreign matters in natural waters, whether deleterious or not.

The high reputation of the author will ensure a wide demand for the book.

The subject is presented in two parts; the first treating of analysis *without* gas apparatus, and part second of analysis by aid of such means.

An ample appendix treats of many interesting collateral subjects, among which are: The Propagation of Epidemic Diseases by Potable Water; The Improvement of Water by Filtration; The Constant and Intermittent Systems of Water Supply, etc., etc.

Several illustrations and numerous tables are added to the text, and will prove valuable aids to the student.

A TREATISE ON THE THEORY OF DETERMINANTS AND THEIR APPLICATION IN ANALYSIS AND GEOMETRY. By ROBERT FORSYTH SCOTT, M. A. Cambridge: University Press. For sale by D. Van Nostrand. Price, $3.50.

This book will be welcome to those mathematical students who are desirous of pursuing their labors beyond the courses of our higher institutions.

The object of the Theory of Determinants is thus explained by Professor Sylvester: "It is an algebra upon an algebra; a calculus which enables us to combine and foretell the results of algebraical operations in the same way as algebra itself enables us to dispense with the performance of the special operations of arithmetic."

Numerous applications are given by the author to lead the student to independent work.

The book is beautifully printed.

A TREATISE ON THE MATHEMATICAL THEORY OF THE MOTION OF FLUIDS. By HORACE LAMB, M. A. Cambridge: University Press. For sale by D. Van Nostrand. Price, $3.00.

This is an octavo volume presenting, in nine chapters: I. The Equations of Motion; II. Integration of the Equations in Special Cases; II. Irrotational Motion; IV. Motion of a Liquid in Two Dimensions; V. Motions of Solids Through a Liquid; VI. Vortex Motion; VII. Waves in Liquids; VIII. Waves in Air; IX. Viscosity.

The higher analysis is employed throughout. A collection of exercises from various authors is given at the end of the volume.

MISCELLANEOUS.

PERIODIC movements of the ground revealed by spirit levels, formed the subject of a paper recently read before the Paris Academy of Sciences, by M. Plantamour. This gives results of a year's observations at Secheron from October, 1878. The east side went down with decreasing temperature until June, there being a pretty exact parallelism between the curves; then the east rose until the beginning of September, in a much greater proportion than the exterior temperature. From 32.8mm. the greatest depression to the east, on January 15, to the maximum of elevation 19.5mm. on September 8 gives 52.3mm. as the total amplitude of oscillation during the year, or 28.08s. There was generally besides a daily movement, with amplitude on September 5, of 3″.2. The minimum is usually between 6 and 7.45 a. m., the maximum twelve hours later. In the meridian direction, the movements of the ground are much less; the total amplitude for the year was only 4″.89. They show an unexplained anomaly relative to the movements east and west. The daily movements in the meridian are very rare, irregular and small. It seems, then, that at Secheron there are periodic movements of rise and sinking of the ground, and that, generally, they are determind by the exterior temperature. Perhaps the configuration and nature of the ground have also some influence.

Interesting Figures which show where the islands and sand-bars in the Mississippi River come from.—From a series of daily observations extending from the early part of February to the latter part of October, 1879, taken at St. Charles, Mo., under the direction of officers of the U. S. engineer corps, it has been ascertained that the average quantity of earthy matter carried in suspension past that point by the Missouri river, between one foot of the bottom and the surface, amounts to 14,858 lbs. per second, or 1,283,731,200 lbs. each twenty-four hours. The matter thus carried along weighs, approximately, 100 lbs. per cubic foot when dry, giving an average of 12,837,312 cubic feet of earth transported each twenty-four hours during the entire year, enough to cover one square mile with a depth of nearly six inches.

During the months of June and July the average quantity, per twenty-four hours, amounted to 47,396,448 cubic feet; enough to cover a square mile with a depth of one foot and eight inches. The maximum quantity observed for any twenty-four hours was on July 3, when it reached the enormous amount of 111,067,200 cubic feet, sufficient to cover a square mile to a depth of four feet. These figures do not take into account the material that is held in suspension within the lowest foot of the depth, or that which is being rolled along the bottom. If these quantities could be ascertained within any reasonable limit of approximation to correctness, there is no doubt but they would show an amount far in excess of that which has already been determined.—T. H. H. in *Missouri Republican.*

The Tay Bridge.—Numerous proposals have been brought forward with the view of solving the all-important problem of how the Tay Bridge is to be put up, and how its safety is to be secured. The latest proposal is by Mr. J. P. Walker, 32 Baker street, Stirling, late of London, who has constructed a model showing how the Tay Bridge could be put in working order at a small expense. The model which he has made only shows one of the center or 250 feet spans. It is not intended to alter the parts of the bridge at present intact, but merely to reconstruct, on a different scale, the part which has given way. The apparent defect of the bridge, as disclosed by the accident in December last, was the construction of the main spans. It is to these Mr. Walker has directed his attention. The columns supporting the ends of each girder are two in number, each being six feet in diameter, and bound together by iron bands. The pillars or columns are each to be ninety-two feet high, or twelve feet above the level of the bridge. The main object of the inventor was to get the 250-feet girders below the center of gravity, and he proposes to accomplish this by means of suspending the girders at either end. To support the girders strong iron bars will be required, but Mr. Walker is confident that there will be no difficulty with this. The bars will rest on top of the columns, and the girders suspended from it by links. Expansion and contraction are thus provided for, and any lateral motion that might occur will not endanger the columns. To increase the strength of the girders, instead of having the network or cross bars as before, it is intended to have vertical rods connecting the top beams with the girders below. The level of the bridge is not interfered with, and Mr. Walker thinks if the law of gravitation had been strictly adhered to at first, the accident would not have taken place.

The St. Gothard Tunnel.—Of the workmen hitherto engaged upon the tunnel, whether at the Goschenen or Airolo ends, nearly 500, who were suffering from what is called the tunnel disease, had left by the beginning of the present month, and have gone to seek renewed health in their homes in Italy. On their departure they were presented by the company with gratuities varying from one hundred to two hundred francs each. The only event of note which has recently occurred within the tunnel was the fall of a large mass of rock, on the 6th inst., by which one man was killed, and five more or less seriously wounded.

By a recent invention paper boxes are made in Boston directly from paper pulp. The boxes are turned out of any size or shape perfectly seamless and of uniform thickness. After drying, the boxes are run through a second machine at the rate of sixty per minute, receiving, under a preseure of 4000 lbs., such embossing as may be necessary. From the time the paper stock is taken from the bales until the perfect box is turned from the machine, manual labor is entirely avoided. By the use of one set of these machines 30,000 boxes can be produced per day, at less than one-third of the lowest market price of hand-made goods, and doing the work of 200 hands.

The engine of the train engulfed when the Tay Bridge fell has been successfully raised. It has lost the funnel, but otherwise is said to be little damaged. As yet it has not been minutely examined, but it is said to be clear that it had not been reversed.

There is reason to believe that the past winter in the Arctic regions has been an exceptionally mild one, and it appears certain that there has been a remarkably early and large break-up of the ice-fields. The American papers think that the Corwin, the vessel about to sail in order to communicate with the Jeannette, and search for a few missing whalers, will find the objects of her search about to pursue their respective voyages.

VAN NOSTRAND'S

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THE STRUCTURE OF STEEL INGOTS.

By D. K. TCHERNOFF.

Translated from Revue Universelle des Mines.

II.

THE feeble cohesion between the prisms is the principal cause of the cracks which appear on the surface of the ingot as it cools. Any inequality in the surface of the ingot, which prevents the contraction of the cooling crust, causes the cohesion of the prisms to be overcome, so that the surface layer instead of extending, cracks open, and this tendency is greater the higher the temperature of the metal.

Fig. 20.

The sides of a crack are of prismatic texture, and the lateral surfaces of the prisms show the impression of the axes of the neighboring prisms. Figure 18, exhibits in natural size one side of a crevice produced at bright red heat, by the hardening of the crust while yet liquid on the exterior.

In the case of an ingot of large diameter ($0^m.750$ to $1^m.30$) and of considerable height (2 to 3 meters), if the steel is very hot and poured rapidly, the expansion of the sides of the mould, being opposed to the contraction of the adherent

Fig. 21.

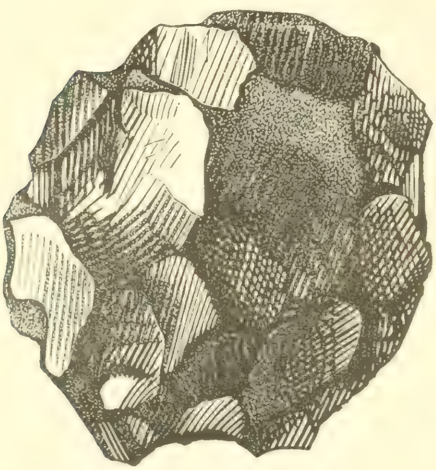
layers of steel, exerts a great influence upon the formation of cracks in the outer surface of the ingot.

The prismatic structure of the exterior of an ingot beyond these cracks leads to the want of cohesion. During

the continuous cooling, and while the volume of the outer layers is diminishing, these latter cannot compress the inner portions which cool more slowly, and this leads to the rupture of the prisms, so that in the exterior portions the effect of cooling is exhibited less by the elongation of the metal, than by the separation of the prisms each from the other, and in such cases involves nearly all the prisms in the ruptured surface (see Fig. 18).

Whatever the origin of the granulation which follows the outside prismatic layer, it is well explained by the elongation of metal when the ingot cools. We have already remarked above that in the slow cooling of steel which has been cast very hot, there results a peculiar

Fig. 22.



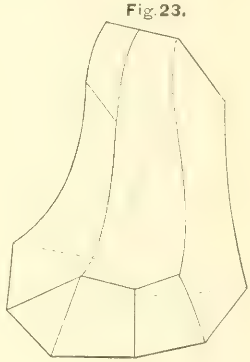
grouping of the molecules in irregular polygonal grains. If, during such grouping, there should be produced, while yet red hot, a rupture of the cohesion, by the action of the exterior forces either of extension or contraction, it is easy to see that the grains would be torn asunder, and that the fracture would exhibit separate grains. As while the temperature lowers from the beginning of the hardening down to the ordinary temperature, the direction of the extensions in different parts of the ingot changes repeatedly, it follows that similar granulations may occur in all parts of the ingot, but more abundantly in the exterior and central layers, and more especially in ingots of large diameter, where the difference in the temperature between the inner and outer portions is greater. It is well to note that in large ingots the outside portions are at first subjected to a force of extension, while the inner portions are compressed. At the end of the cooling, on the contrary, the outer layers are compressed and the inner extended.

The elongation of the interior portions of large ingots (of one meter in diameter) is so great that, when the ingot is exposed to the air to cool it presents, when cooled, interior cracks, generally in the portion where it is the weakest.

A single granule of steel, enlarged about three times, is shown in figure 22. Another one, from a different source, is exhibited in figure 23.

Figures 20 and 21 represent on a re-

Fig. 23.



duced scale (about one-third size), fractures of a highly granulated steel.

These sketches show that the grains bear only a feeble resemblance to crystals; no regularity of form is apparent; for, besides the complete diversity of angles, there is a distortion not less complete of the faces.

We will now consider the means of dealing with the defects we have been describing.

As an indirect method I will refer to the preparation of malleable cast-iron. In casting pieces of clear white cast iron, and heating them for a long time in an oxidizing medium, a product is obtained which is more or less decarbonized and is not especially different from either steel or wrought iron.

This method does not really solve the problem, for the metal obtained by this process is far from possessing the properties which we look for, although malleable cast iron has found many useful applications, especially in locksmithing.

Without considering longer this indirect method, we will proceed at once to consider the means of combating the defects of ingot steel.

There are three methods:

1. Casting the ingot in the simplest form, and then shaping it by hammering and rolling.

2. Subjecting the steel while in the liquid state to a strong pressure, and obtaining an ingot without bubbles, and (in part) without a shrinkage cavity, then rolling or hammering as before.

3. Arresting by some chemical process the disengagement of gas from the melted steel, and then casting the steel in metal or sand moulds in the desired forms.

In the first case, the structure of the ingot would be similar to that of figure 1. The defects developed are of the two kinds shown in the right and left hand sides of the figure. The upper part of the ingot full of cavities is rejected. It forms from one-fourth to one-sixth of the weight of the ingot. The remaining part only is used for purposes of manufacture. The use of steel at the present time for armor and heavy artillery requires ingots of large dimensions. A corresponding increase in the size of machines to work these ingots is, of course, demanded. The hammer of fifty tons has become insufficient. At the Paris Exposition of 1878, a mould of a stamp of eighty tons was exhibited, designed to work an ingot of 120 tons, of which the model in wood was also shown. During a visit to the steel works at St. Chamond, I saw a double-acting steam hammer of eighty tons in actual operation, and it is proposed to construct at Krupp's works a steam hammer of 100 tons weight. I regret that I do not know the present condition of this question.

In order to avoid unnecessary labor in forging, they try to cast the ingots of such a thickness that the transverse section is double that of the piece desired. In preserving this ratio of thicknesses the exterior porous layer, diminished by oxidation during the working, as well as a certain thickness removed by turning or planing, leaves sufficient to admit polishing the finished piece. This metal removed by turning or planing is in many cases from 10 to 20 per cent. of the weight of the finished piece; so that this added to the rejected upper part of the ingot represents a considerable loss.

It is well to remark that in working thus, the porousness of the interior portions of the ingot, that is to say, the area of local contraction diminishes slightly in the direction of the length, by reason of the lengthening of the shrinkage cavities in common with the metal surrounding them.

In the cross section of the ingot the influence of the local contraction upon the solidity of the steel is yet more sensible. This becomes apparent by experimenting upon the strength of different layers of a large rolled ingot. The following table exhibits results of some experiments.

Figure 26 represents an ingot of diameter D′ hammered to the diameter D. A hole of diameter *d* is drilled through the ingot. Then thin laminae *a* have been cut parallel to the axis of the ingot and subjected to a tensile force in a testing machine. The diameters D′, D, and *d* are variable.

D′ in inches.	D in inches.	*d* in inches.	Number of the Slice.	Limit of Elasticity in Atmospheres.	Breaking Strain in Atmospheres.	Elongation. Per cent.
47,5	36,5	11	1	1800	5300	16,0
			7	2330	6200	17,0
42,5	32,5	9	2	1980	5200	18,0
			6	2500	6400	16,0
36,5	26,5	8	2	1800	5830	13,7
			5	2380	6540	14,8
36,5	26,5	8	1	1860	4517	16,0
			7	2910	6585	15,0

As the ingots from which these specimens have been obtained were forged, it is fair to inquire whether the difference in strength of the interior and exterior layers may not be explained as due to the working. It is necessary to remark that these ingots, after having been rolled were heated and then more or less slowly cooled; and as in this operation the different layers of the ingot

were not under identical conditions, each separate sample before testing was reheated and cooled slowly; so that the influence of the working upon the ingot was much reduced, and the difference in strength is fairly to be attributed to the influence of the local contraction cavities. It is to be regretted that no similar experiments were made upon ingots of similar dimensions that had not been forged.

In order to be convinced of the existence of these cavities of local contraction, it is only necessary to examine Figures 24 and 25 which represent, on a reduced scale (about half size), examples similar to those employed in our experiments; they are polished slices or laminæ cut along the radius of a forged ingot. From the figures we see that, in working, these little cavities are elongated in the direction of the axis, and have taken an elliptical form, and that the number of cavities increases as we approach the middle of the ingot.

Fig. 26 shows at b the place from which the slices were cut.

II. We will now consider the method of making compact ingots by compressing the liquid steel. The effects of cooling steel which we have observed indicate that we can obtain a cast metal free from bubbles, if we can cast it under a pressure sufficient to hold the contained gas in solution. We may cite here among other examples the proposition of Galy-Cazalat, in 1866, to cast steel under a pressure obtained from powder; also the method of Chaléassiere, in France, where the liquid metal was subjected to a steam pressure of 6 to 10 atmospheres.

These means, although rational in principle, have not been extensively employed on account of the difficulties

Fig. 24.

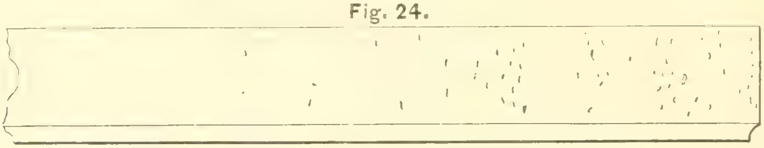
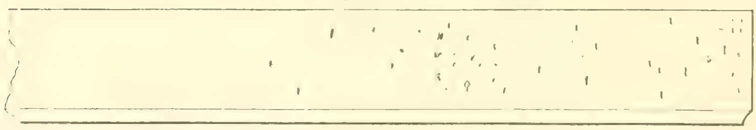


Fig. 25.



encountered in employing them on an extended scale.

It is much more simple to apply a piston directly to the liquid steel when in the mould. As this method of preparing *compressed steel* has been somewhat extensively employed, we will briefly consider it.

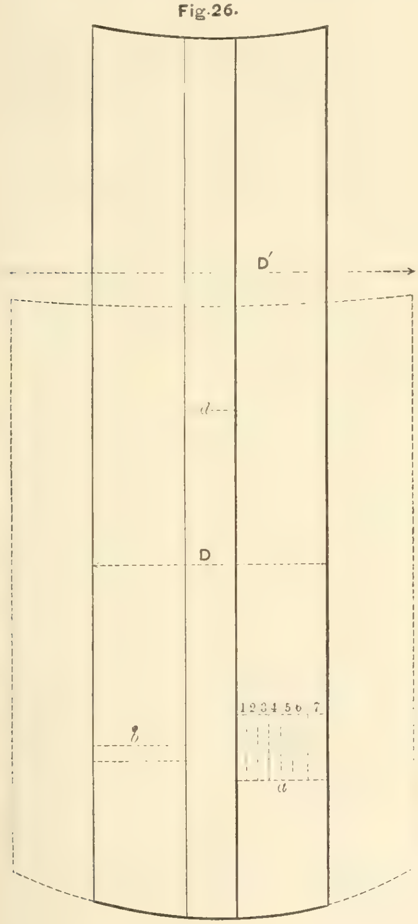
The steel is poured into a mould in the ordinary way, and is immediately subjected to the action of a solid piston worked by a hydrostatic press. The gas, which is partly disengaged, accumulates to some extent around the sides of the mould, by reason of the strong pressure is redissolved.

In order that these bubbles around the sides should be absorbed, it is necessary that the metal here should remain in a liquid condition for as long time as possible. To insure this the sides of the mould are lined with a refractory and non-conducting material. After the introduction of the piston a pressure is exerted, until a sufficiently thick solid crust is formed on all sides to prevent the formation of bubbles. If this were the only object of the use of the piston, only a slight pressure would be necessary, for this would prevent the disengagement of gas. But when it is designed to prevent the formation of the "funnel" arising from shrinkage, a great pressure is required, as the piston is required to follow the contraction of volume until the center solidifies. To accomplish this, Whitworth constructed a press of colossal dimensions. The diameter of the piston was $1^{m}.25$, and the pressure obtained 650 atmospheres;

the piston being urged by a force of 10000 tons.

It is difficult to say to what extent the central shrinkage cavities in large ingots can be prevented by means of such a press; for an ingot exhibited by Whitworth at Paris, cut lengthwise and polished, had a diameter only of $0^{m}.30$ to $0^{m}.33$, and a length of $0^{m}.80$ to 1 meter. At the distance allowed by the glass case the shrinkage cavities could not be detected, and the fracture seemed quite compact.

Fig. 26.



The compression of liquid steel, notwithstanding its apparent advantages, has not yet been employed in castings, or pieces of complicated form. Moreover, it is known that Whitworth was not content with simply compressing such forms as rings, common bolts and tubes, but that he afterwards subjected them to the steam hammer. Thus, compression alone has not solved in a complete manner the question of casting steel; it has only resulted in the economy of metal arising from saving the upper portion of the ingot. But the results are too costly; the outlay necessary for the press and other accessories, to which is to be added the cost of the labor of compression, is far from being covered by the saving of the metal. For such reasons the application of Whitworth's press remains confined to the establishment of the inventor.

III. We will pass to the third method which differs from the preceding, inasmuch as it has resolved the difficulty in a more complete manner, and rests upon recent theoretical researches.

In the matter of high steel, this problem was solved in part some 20 years since, at the steel works at Durham, under the direction of the engineer Mayer. It was applied to many uses in Germany, Austria and England. Among other objects the bells of Bochum enjoyed and still enjoy a special reputation. Thus far they have manufactured about 3000 bells. It is also known that locomotive driving wheels, steam engine cylinders, propeller wheels, cylinders for hydrostatic presses, gear wheels, etc., etc., have been made at these works.

They made all the objects in moulds of a steel melted in crucibles. The charge is composed in great part of iron rich in silicon. When the means, held for a time secret by the makers, became more or less known, chemical analyses revealed the fact that the compactness of the product was due to the presence of silicon, which yielded a steel free from contained gas. And this for two reasons; at first the silicon diminishes considerably the capacity of the liquid steel for dissolving gas, and further, it prevents the disengagement of the carbonic oxide which is produced by the action upon the carbon of the steel by the oxygen of the ferric oxide dissolved in the steel.

Now, as in fusing in crucibles, the steel is preserved against the oxidizing action of the air, and as its relative hardness diminishes the chances of dissolving the oxide of iron, it follows that the preparation of castings without

bubbles from crucibles does not present such difficulties as arise in the making of mild steels by the Bessemer or Martin process.

If we may judge by the products exhibited at Paris, the manufactory at Terre Noire has conquered the difficulties of casting mild steel free from bubbles.

To the engineers of Terre Noire, under the direction of M. Euverte, is due the credit of having produced on a large scale, ferro-manganese compounds rich in manganese. At present they make this metal containing 80 to 85 per cent. of manganese.

To these gentlemen is due the credit of the new plan of introducing a large quantity of silicon into this alloy, from whence has come the possibility of producing Bessemer or Martin mild steel without bubbles.

It is known that in the Bessemer, Martin or Pernot processes, the silicon contained in the charge is oxidized even at the commencement of the operation and passes into the slag. An exception is presented in the hot process of Bessemer in the case of cast iron rich in silicon. There is nearly always obtained towards the end of the operation a metal free from silicon, and as the spiegel-iron or ferro-manganese contains very little, the steel has hardly any more. Such is the cause of the presence of gas and of oxides in solution in Bessemer and Martin steels, and such is the reason why a greater part of the ingots are full of bubbles. The alloy of ferro silicide of manganese made at Terre Noire, affords a means of introducing into the final product a quantity of silicon, sufficient to dispose of the oxide of carbon and to form a bisilicate of iron and manganese, by the reduction of the oxides of iron contained in the steel.

This bisilicate being liquid and fusible comes pretty soon to the surface, and in this way the metallic bath is relieved entirely of the particles of scoriae which injure the physical properties of the steel.

According to what we learn from M. Pourcel, the new alloy is added at the close of the operation and before casting, in such quantities that the steel, when cast, shall contain 0.2 to 0.3 per cent. of silicon. In order to neutralize the injurious influence of the silicon, it is necessary to introduce a quantity of manganese, such that the ratio between it and the silicon shall be that of their molecular weights; that is, so that

$$Si \times n : Mn \times i :: 3 : 4.5.$$

Steel thus made is cast without ebullition, and yields ingots without bubbles. In order to diminish the cavities of local contraction, they cast the upper part with a waste piece as in iron castings. The beautiful collection of specimens from the Terre Noire works, exhibited at Paris, indicates that the manufacture of steel articles by casting is well-nigh accomplished.

It remains only to reduce the quantity of silicon to be added to the smallest possible amount, in order that not too much manganese shall be required to neutralize it and abstract the carbon from the combination. We may hope to arrive, by this direct method, at a victorious solution of the problem of casting objects in steel.

We will enumerate the articles exhibited at Paris from the Terre Noire Works.

1. Two shells of 32 centimeters' caliber which pierced an armor plate backed by wood to the thickness of a meter. The shells had been fired against the plate at an angle of 20 degrees. The shape of the forward part only was changed. The upsetting along the axis amounted to 14 to 19 millimeters; the entire length of the shells being 787 and 785 millimeters. The enlargement was about .05 millimeter, and the deviation of the point 17.5 to 27 millimeters.

2. A ship cannon of 14 centimeters. The cannon had been examined by the "Commission des Essais Maritime et d'Artillerie" at Ruelle. 100 shots had been fired from it with charges of powder weighing from 4.2 to 4.9 kilograms; the weight of the ball increasing from 18.65 to 21 kilograms. After these experiments it was found that the change of form was less than in a wrought steel gun subjected to similar conditions.

3. A tube which had resisted a trial with powder at Bourges.

4. An ingot of $11\frac{1}{2}$ tons weight for a cannon, roughly turned.

5. Tubes for cannon of 24 to 32 centimeters caliber; a ring for a cannon trun-

nion of 42 centimeters weighing 6½ tons; a connecting rod for a steam engine of 400 horse power; a crank shaft for a locomotive, etc.

All the pieces exhibited from Terre Noire, judging of them after their surfaces were polished, would compare favorably with the best samples of iron. Yet in the fracture of the ingots could be distinguished small cavities of local contraction of which mention has been made above.

In observing the hollow surface of the bubbles, it is noticed that the lower part has a smooth hemispherical contour, and that the sides, especially at the upper part, are covered with dendritic crystals of different forms. (Fig. 27). In comparing carefully these dendrites with the

Fig. 27.

crystals of the contraction cavities, it is easy to detect a resemblance, and to see that the dendrites are derived from the forming crystals in the steel, as they are in the act of forming at the moment the bubble is arrested in rising to the surface.

The bubble in rising produces a motion in the liquid; a rotation and a separation of the crystals which are floating, but as the crystals have the same temperature as the liquid, they redissolve in it with great facility, so that the bubble of gas, in rising among the crystals, causes some to be partly dissolved; bends some and, forcing them together, causes them to take dentritic forms of the most capricious character, among which it is sometimes nearly impossible to trace a resemblance to the crystals grown in the steel which formed them. (See Fig. 28.) One of these dendrites is represented in figure 29.

It results from this that to destroy the growing crystals, that is to say, to

Fig. 28.

redissolve them in the liquid steel, it will suffice to produce a slight motion, for the motion of the bubble in rising is nearly sufficient to accomplish it. This circumstance permits us to conclude that it is possible to break up the prismatic structure of the exterior por-

Fig. 29.

tions of steel ingots cast in a metallic mould, and that it is possible also to destroy the local contraction cavities or porosities of the central portion of the ingot.

If then, during the pouring of the steel, a rapid rotation be given to the mould, the crystals which are forming normal to the sides of the mould cannot grow so rapidly as when they are left at rest, and consequently the solidification of the steel would be by united and amorphous layers. If the rotation of the mould be continued, the solidification of the ingot must proceed by layers as united as those near the sides, and as the cause of the local contraction cavities has been removed, the central porosities will be wanting, and the result will be a compact mass which requires neither the press nor the steam hammer. It will suffice to reheat the ingot to destroy the granular structure which it takes on after solidifying, and then to cool slowly. As at the commencement of the casting the growth of the crystals is rapid, owing to the cooling effect of the mould, therefore the rotary motion should be as rapid as possible at the beginning.

It is necessary to observe that as the liquid metal will slowly take up the rotary motion, it will be necessary to reverse the direction of the rotation of the mould quite frequently and suddenly.

For cylindrical ingots which are to be bored through the middle, such as ingots designed for cannons, it is more convenient to rotate them around a horizontal axis, by turning the mould upon its side as soon as a crust covers the surface. For shells widest at the center, the inclined position is preferable. It is certain that by keeping the metal thus in constant motion, homogeneousness is assured.

This method recalls that which has been called centrifugal casting, but the resemblance is only apparent.

In effect, if by the method of centrifugal casting we succeed in obtaining a compact metal, it is due simply to the motion of the liquid which prevents the formation of crystals. But the compactness can only be obtained at the surface, and at the expense of the center. This would be practical in the case of cast chilled rollers, of cannons, cast shot and some articles in bronze, etc., etc.

It remains to consider a question which was raised some ten years ago by my communication upon the structure of steel. "Is it necessary to work the steel even if the casting be compact, that is to say, without local contraction cavities?" In order to reply to this question it will suffice to refer to the experiments of our commission in 1869 (published in Russia in 1870). But I will cite some made more recently. Tables I. and II. suffice to show the inutility of any compression to improve the physical properties of steel. All the difficulties are in casting. The difference in the physical qualities of steel cast and not annealed, compressed or not, and steel annealed and worked, consists in the texture of the grains, in the presence of local contraction spaces, but especially in the granulation. This latter appears to give rise to extensive forces during the cooling from the red heat.

At the commencement of solidification, the exterior portions are subjected to these forces; at the end of it the in-

TABLE I.

EXPERIMENTS UPON TENSILE STRENGTH OF SAMPLES OF STEEL FROM THE TERRE NOIRE WORKS.

Diameter of Sample, 14 Millimeters.
Length of Sample, 100 Millimeters.

Character of Sample.	Elastic Limit, kilos. per sq. centimeter.	Breaking Strain, kilos. per sq. centimeter.	Elongation, per cent.	Remarks.
1. Hammered Steel:				
Carbon 0,150	2200	3570	34.0	Containing—Manganese, 0.25%. Silicon, a trace.
" 0,490	2620	4880	24,0	
" 0,709	3160	6800	15,0	
" 0,875	3420	7410	9,5	
Hardened in Oil:				
Carbon 0,150	3280	4680	28,6	
" 0,490	4460	7050	12,0	
" 0,709	6880	10710	4,0	
" 0,875	9050	10600	1,0	
2. Steel Cast only:				
Carbon 0,287	2100	4470	8,8	Containing—Manganese, 0.75%. Silicon, 0.25%.
" 0,454	2650	4330	3,0	
" 0,750	3050	6420	3,5	
" 0,875	3920	6450	1,5	
Hardened in Oil and annealed:				
Carbon 0,287	3160	5180	24,6	
" 0,459	3350	5550	19,2	
" 0,759	3580	7420	14,3	
" 0,875	4609	8260	3,5	

TABLE II.

RESULTS OF EXPERIMENTS UPON THE TENSILE STRENGTH OF STEEL FROM THE WORKS OF OBOUCHOW.

Diameter of Samples, 12,5 Millimeters.
Length of Sample, 150 to 250 Millimeters

Kind of Specimen.	Elastic limit in atmospheres.	Breaking Strain in atmospheres.	Elongation, per cent.	Remarks
Eight-inch Shot of Bessemer Steel:				Mean of two analyses.
Not hammered.				
Not reheated	2800	6000	4,0	C=0,70; Si=0,07; Mn=0,54.
Reheated	3800	7100	8,0	
Bessemer Steel, worked	2700	6000	16,5	C=0,43; Si=0,04; Mn=0,30.
"	2810	6100	15,5	
Bessemer Steel Ring for a 9-inch Mortar, hammered and annealed				C=0,35; Si=0,01; Mn=0,12.
Mean of several samples	2800	7400	14,0	
An 11-inch Shot from Krupp's Works, hammered	—	6900	10,0	C=0,45; Si=0,01; Mn=0,30
A 9-inch Shot from Terre Noire, annealed,	3800	7100	3,4	C=0,68; Si=0,23; Mn=0,29.
not hammered	4000	8100	5,6	C=0,57; Si=0,24; Mn=0,29.
A 9-inch Shot from Iznoskow, hardened, not worked	5600	5600	0,4	C=0,72; Si=0,22; Mn=0,61.
Steel cast under pressure of 1200 atmospheres, without being worked	2833	4666	2,4	Crucible Steel, containing 0,54 carbon. Mean of 6 samples.
Reheated	3175	5275	6,7	Mean of 4 samples.
Worked and annealed	3200	6400	16,0	Mean of 2 samples.
Steel compressed by 1200 atmospheres....				
Worked and annealed	2650	4900	18,1	Mean of 2 samples.

terior portions. Whitworth's method of casting with a core is very disadvantageous, inasmuch as the core prevents the free contraction of an ingot with a hollow center, and there is a force tending to elongate after it solidifies, a condition that leads to granulation. Such is the cause of the low ductility of compressed steel in the form of an annular ingot even after it has been reheated. It appears that Whitworth hammered his steel, which had been already compressed, and it is only in such way that a compressed steel hollow ingot can be made to compare favorably, in physical quality, with the steel of the Terre Noire Works, which has been cast and softened by fire. This is shown by a comparison of Tables I. and II.

From what has been said above it may be concluded that the problem of manufacturing articles in steel by casting in a mould, is now substantially solved, that is to say, with reference to compactness. We obtain this condition by casting very hot, by introducing silicon, or finally by compression under a force of 6 to 10 atmospheres. To give the steel its best structure and the most desirable mechanical qualities, it is sufficient to subject it to a reheating followed by a cooling more or less rapid.

In casting articles in steel especial care is needed to avoid the porosity arising from contraction and the granulated or prismatic structure. The causes of local contraction spaces, as we have observed, may be removed in various ways. According to my theory the motions of the liquid in the solidifying portions should be regarded as of first importance. The employment of moulds of earth; bad conductors of heat; the slow cooling of the steel in the moulds; the absence of obstacles to the free shrinkage of all the parts during cooling, will prevent granulation. By these

means we may avoid the defects in castings.

These conditions may be fulfilled in case of articles of very simple form, by employing an iron mould with thick sides, pierced with numerous holes, and lined with some fine-grained refractory material. This enables us to avoid raising the metal to a very high heat, which is of great importance as regards granulation. Compression by means of a piston has no future, and is of importance only in the most simple forms.

Steam hammers and rollers are indispensable for the manufacture of pieces having such dimensions as to prevent employing the precautions which insure compactness, especially if the surface is to be polished.

FORESTRY IN FRANCE.

From "The Builder."

Considering the great importance of the preservation of forests, and the lamentable want of foresight, which permits their reckless destruction in nearly all parts of the world, but more particularly in our own continent, where forests will soon become scarcer and scarcer unless more practical measures are adopted for their preservation, it is satisfactory to be able to note that some Governments are recognizing the advisability of attempting the preservation of the forests they have under their charge. One of these, we are able to learn from a report published during the late Paris Exhibition, is the Government of France. The document in question, at the time it was issued, did not attract the attention it really deserves, and on that account we refer to it here somewhat fully.

Before proceeding with the report, let us state shortly the extent of forest land in France, as given in *Engels Statistische Correspondenz.* The French forests cover a surface of about 22,688,000 acres, being about 17 per cent. of the total area of France, making her one of the European countries poorest in forest land.

Here it will be of interest to mention that Sweden, of European countries, has still the largest percentage (43 per cent.) of forest-covered soil, notwithstanding the enormous waste that has been going on almost for centuries. Next follow Russia, with 37 per cent.; Bavaria, 32; Austria, 30; the German States (excepting Bavaria and Prussia), 27; Prussia, 23½; Switzerland, 18; France, as above noted, a little over 17 per cent.; Italy, 17; Belgium, 13 to 14; Holland, 7 to 8; Spain, 7; Denmark, 5; and Portugal with 3¼ per cent. Great Britain ranks next to Portugal, having only 4 per cent. of her area covered by forests.

The French forests are very unequally distributed over the country. Leaving out the department of the Seine, which has only 2 per cent. of forest land, the department of the Manche has the least (3 per cent.), while in that of the Landes the proportion is 47 per cent. or nearly half. The forests cover:

			per cent.	
In 18	departments,	below	10	of the soil.
In 42	"	from	10 to 19	"
In 17	"	"	20 to 29	"
In 8	"	"	30 to 39	"
In 2	"		40 per cent. and over of the surface.	

Forests in France are for the most part private property; the Government owning 10.7 per cent., the departments and communes 22.4, public institutions 0.3, and private owners 66.6 per cent. of the forests.

It will be seen, therefore, that the State can do but little directly. The little influence it possessed has gradually decreased. But the law of 1860, to be referred to more fully presently, has somewhat changed this. The Government is now able to prevent the wilful destruction of forests, and to cause the afforestation of waste lands.

Now as to the report to which we have referred. In France the administration of the forests is associated with that of water, under the department styled the "Administration des Eaux et Forets." On the whole, the sphere of its operations is much restricted; forests, as already remarked, are scarce in France;

extensive inundations, on the other hand, are unfortunately of very frequent occurrence in that country.

We learn from the report that a large proportion of forest land does not necessarily exclude a numerous population. Compared with Germany, France has a third less of forest-covered soil, at the same time that she has a population less dense by one-eighth. Belgium, Holland, Denmark, and Great Britain, being either countries with a proportionally large sea coast or else islands, with an especially damp climate, may be left entirely out of the comparison, as they are able to exist without extensive forests. But there is no question that the retrograde process of Spain, her less dense population, is due in no small degree to the absence of forests, more especially as the uniformly mountainous nature of her soil requires, more than any other country, the prevalence of forests. Wherever this test is applied, it will be found (of course, speaking only of European countries) that fertility and density of population are closely connected with the presence of forests. It would form a generous undertaking for any Government to aim at an equalization in this direction. Whatever has been done in this respect in all countries has only been effected piecemeal; consequently it has been of but little influence on the whole. A common mode of procedure is what is wanted.

So also in France. It will be remembered by visitors to the Paris Exhibition that the display made there by the Administration des Eaux et Forets formed one of the most important and instructive collections of that exhibition. The Administration had erected on the slope of the Trocadéro a real palace of wood in the charming Swiss style, to which had been added some outbuildings, among which was a forester's house, constructed of round wood and billets, framework, straw, brushwood, &c. The purpose of the wooden palace was indicated also by products of forestry and tools used in forests fixed to the outer walls and the verandah. The interior formed one large and high hall, in which nothing was wanting that could supply information about French forests. Specimens of the soil and wood of all descriptions, stuffed animals, a beautiful collection of insects and illustrations of their useful or injurious activity, tools of all kinds, a complete library, herbaria, &c., were appropriately arranged, while the surrounding garden grounds contained all the trees and plants of the forest in selected specimens.

The experience gained by the French Office of Woods and Forests with regard to the acclimatization of foreign, especially trans-oceanic forest trees, is particularly valuable. The blue gum tree imported from Australia prospers in the South of France, and by its plantation at the mouth of the Var the marshes surrounding it have been drained, and the fevers formerly prevailing there banished. The trees prosper wonderfully in Algiers, as the section of a trunk not yet fifteen years old, of a diameter of 1 foot proves. But the wood is white, light, breaks easily, and cannot be compared with the durable, solid ship timber which the same tree produces in Australia. The same is the case with the American oak, which prospers in poor soil, grows quickly, and forms beautiful tops of foliage. But the wood is inferior, the bark contains less tannin than that of European oaks. Trees, consequently, can be planted in certain cases only as surrogates, principally to prepare the ground for better kinds. At present, experiments are also being made with the Calfornian theya tree, the wood of which is especially suitable for better classes of furniture; it is doubtful, however, whether its wood will not deteriorate by cultivation in Europe.

But the most important feature of the forest exhibition was the illustration of the planting of trees in places which require afforesting. This includes two very distinct categories, the afforesting of heights and the afforesting of dunes, as well as their turfing, for trees cannot prosper without the growth of grass. On the heights as well as on the sandy shores of the sea, the labors of the forest cultivator meet with unusual obstacles.

The bare lines of hills have, in winter, a superabundance of snow and water, while in summer they suffer from longtinued drought. By afforesting both evils are to be remedied, but the tree itself suffers most from them. The winds and storms to which the tops of

mountains are exposed, and against which the trees are to protect them, as well as the slopes and the valleys which they form, are also a great drawback to the growth of trees. The forester must consequently apply especial means for attaining his object, the afforestation of lines of hills.

There are many depressions in mountains where the evils indicated are not so pronounced, and some protection against wind and too great drought is found. But the water, or rather the masses of water which are collecting in these depressions when the snow melts, have always sought an exit, and, as they are acting with continuous and, on that account, resistless force, found it. Each depression, each sinking of the soil in mountains, has been formed, long before the existence of man, into channels and gorges, whence in spring enormous bodies of water have precipitated themselves into the plains below, carrying with them masses of stone, earth, and roots. The first step, therefore, is to provide the gorge, which very often has been expanded into a valley, with obstacles against the precipitation of water. Weirs are consequently constructed at suitable distances across it. They either consist of a row of strong piles, the intervals between which are filled up by hurdle-work, or a strong, well-constructed dike is built of blocks of rock. The weirs must be made stronger and multiplied according to the length of the gorge and the quantity of water to be met. They retain the water for some time, which forms by its own action a broad, smooth course, a small lake; all the small stones and dissolved particles of earth settle down, and soon form a broad, deep layer of fertile soil, on which grow first grasses, then bushes, and finally trees. Humidity is here longer preserved by the water kept back, and the edges of the gorge afford some protection against winds and a too powerful sun.

As soon as bushes and trees have risen above the weirs, afforestation proceeds and extends rapidly. More fertile soil and humus accumulate, the gorge is gradually filled up, its slopes and edges become covered with grass, and upon grass follow regularly bush and tree. It becomes possible to lead the water from the weir by a horizontal channel over the edge upon the surface of the mountain, or rather the slope, where then the same series of growth is repeated. The verdure and trees already existing afford protection and supply moisture to the plantations growing on both sides of the filled up gorge. The mountain thus becomes gradually covered with wood from the gorges. The further bush and tree are extending the longer snow and moisture are kept back, the waters rushing towards the gorge decrease, lose in violence, whereby the matter they carry with them is precipitated, and kept back more completely, and, in a corresponding degree, more nourishment conveyed to the plants. The impetuous mountain torrent, which during the short term of its yearly existence only causes mischief and devastation, is gradually tamed, but it flows during a longer period, for the snow retained by the trees no longer melts all at once. The further afforestation advances the further this development proceeds. Finally, the mountain is transformed into a quiet forest brook, which fertilizes the gorge by degrees almost entirely filled up, and never dries up. The mountain covered with forest makes the precipitation of moisture possible; springs break forth, whose waters seek the bed of the old tumbling and plunging torrent.

In the plain, also, this beneficial change makes itself felt. The never failing brook drives mills and machinery; it serves for the irrigation of meadows, fields, and gardens. On the lower slopes, since afforestation has been effected, vineyards, orchards, or fertile, if rugged, fields have sprung up. The afforested mountain protects from cold, excessive humidity, and exceeding aridity alike, but especially also from inundations. It tempers wi ter, cools summer, and prevents especially many of the late night frosts which are so destructive to many of the most fertile plantations.

It is principally mountain chains of medium height where such works are possible as we have here pointed out. But lines of hills of small elevation, or swellings of the ground as we meet them in large plains, exert a similar influence on climate and weather if they are covered by forests. A great many

will, at the present day, smile incredulously when they read how in the Middle Ages vineyards existed in all parts of Northern Germany, and a not inconsiderable trade was carried on with their products. And yet the explanation is as easy and as simple as it can possibly be. At that time nearly the whole country was still covered by large tracts of forest, the winters were consequently somewhat milder, frosts ceasing earlier in spring. As a matter of fact, wherever the vine is cultivated in Germany at the present day, there we find the largest forests. Examples are not rare that as late as this century villages have suffered injury in the cultivation of the vine, or entirely lost it, because forests in the neighborhood have been destroyed. There is no protection in Germany against this wholesale destruction of forests. It is true there is a Ministry of Agriculture, and there are Boards of Health, but there is an absence of legislative enactments for the preservation of forests. It has been repeatedly suggested that existing German forests should be preserved, and, where practicable, schemes of afforestation carried out; at present, however, without any visible effect.

In France the state of the question is in a no more advanced condition. Afforestation proceeds but slowly, and yet France is acknowledged to possess the best law for afforesting mountains. From 1861–77 but 68,000 acres of mountain land were planted with trees, and further 3,700 acres turfed. The sum expended in those seventeen years was only £345,000, really an absurdly small amount for a country which has spent milliards on the improvement of Paris and other similar outlays, and which is on the point of expending other milliards on railways the utility of which is at least problematical. Need we wonder if inundations occur periodically, every time causing injury calculated by hundreds of millions?

The French law of afforestation already referred to, and passed in 1860, orders in its essential provisions that afforestation is to be promoted by public grants of seeds, young trees, money, and other means. Afforesting, if the state of the soil and other conditions make it appear necessary, may be made compulsory. If landed proprietors, communes, and others interested should decline to undertake themselves a regulated system of afforestation, this may be effected by the State, which may take possession for this purpose of the land in question. If persons interested wish, after completed afforestation, to enter again into possession of their soil, and consequently enter upon the enjoyment of the improvements effected by the State, they must repay to the latter the expenses incurred with interest, or cede instead half of the afforested soil. If, notwithstanding this excellent law, proportionately little has been done in France for afforestation, this must be ascribed to the selfishness of the communes and individual persons concerned, which has not been overcome even by the severe trials of inundation. The instability hitherto of the French political system has been suggested as the cause of the little regard paid by prefects and other officials to the subject. It is said that their attention has been so much engrossed by electioneering and other political work that little time is left for undertakings which require years of labor before any tangible result can be shown. We need, therefore, feel no surprise when it has been tried to connect the frequent inundations in France with the carelessness engendered by repeated political changes.

Amongst the relief plans of afforestation effected that were exhibited at the Trocadéro, that of the Torrent du Bourget is the most remarkable. A plan represents the broad, desolate gorge (near the Barcellonnette in the Basses-Alpes) in its state of 1868—everywhere, only naked rocks and sterile tracks of rubble. The hollow has since been half filled up by the construction of powerful high dams of stone. Trees and bushes, as well as the turf, reach in some places as far as the edge of the gorge, while in its middle the former forest torrent has already visibly assumed the quieter, steadier course of a regulated brook. The valley below has never since been visited by the formerly periodically recurring devastating inundations.

The solidification of dunes by means of the growth of grass and the planting of trees offers difficulties of another kind. The question here is to "fix" the sand hills and sand heaps, shifted and

driven about by the waves like balls. The work must be very gradual. A whole series of dunes is marked out, the line being drawn, as near as possible, over their crests. The parting off is effected by means of a strong fencing over the crest of the dunes, towards which smaller cross fences lean herring-bone fashion. The effect of this construction is the accumulation of ever increasing masses of sand in the places thus protected, which eventually form a bulwark for the space behind against the rush of the waves. The area thus enclosed is first planted with meadow grass, and next with coniferous trees, the latter being at first protected against sand drifts by means of brushwood. Sedges, broom, esparto grass also have been employed with advantage for first cultivation. The exhibition contained relief plans of the dune works and plantations of the dunes between the mouths of the Gironde and the Coubre. The soil reclaimed lies partly below the level of the sea, and amounts already to many thousand acres. Where, a hundred years ago, there was only a desolate and marshy expanse, there the eye now ranges over splendid forests, in which deciduous trees begin more and more to show themselves among firs and pines, while prosperous looking villages and large herds of cattle, gardens, and vineyards impart life to a landscape which was formerly a silent and dreary waste.

ON THE VARIATION DUE TO ORTHOGONAL STRAINS IN THE ELASTIC LIMIT IN METALS, AND ON ITS PRACTICAL VALUE AND MORE IMPORTANT APPLICATIONS.

By ROBERT H. THURSTON, A. M. C. E.

From the Transactions of American Society of Civil Engineers.

The writer has, in various earlier papers, called attention to the important effects of strain in metals in the elevation of the normal elastic limit, and has shown that strain in tension causes in iron a permanent exaltation of that limit, which exaltation may be subsequently taken as a measure of the strain upon which it is consequent; thus overstrain causing accident may be detected by the permanent record so left in the altered character of the metal.

After a long series of experiments and special investigations, the results of which will be found in papers presented at various dates to the American Society of Civil Engineers, the writer fully determined these facts, and confirmation was found in the researches of Beardslee and others. It was also found by the writer that a definite law governed this exaltation of the elastic limit, relating its amount to the time allowed for set to take place, and to the rate of distortion by unintermitted stress. This law was expressed by a formula of the form

$$El = a \log. t + c.$$

in which, though very variable with differing qualitities of metal, for good bridge and cable irons, $a=5$; $c=1.5$; El=per cent.; t= time in hours

The fact was discovered during researches conducted by the writer in the Mechanical Laboratory of the Stevens Institute of Technology, that this same modification of the elastic limit occurs when metals are transversely strained, and this was announced to the American Society of Civil Engineers in a paper presented March 1st, 1876, in which it was shown that in what was called the "iron-class," comprehending both iron and steel, this effect is one of elevation, while, as had been already also shown, on the "tin-class," including the brasses and the bronzes, the effect is to depress the normal elastic limit. Strain-diagrams exhibiting the behavior of the several kinds of metal under these strains, were given as conclusive evidence of the facts presented.

The fact that a permanent distortion of a piece of iron increases its stiffness had been long known. Bell-hangers had, from some unknown but very early date, been in the habit of stiffening wire and

guarding against subsequent stretching while in use, by straining it considerably before putting it in place. As early as 1850 Clarke remarked, ". . . if the compressed and extended portions of a wrought iron bar could be, by any artificial means, permanently strained previously to its employment as a beam, such a beam would deflect less than a new bar, and would be practically a stronger beam, since the strength is regulated solely by the bending of the bar."

This idea was also practically applied in 1854 by Werder, at Munich, who stiffened his rods before placing them in the structure, by giving each a permanent extension by tensile stress exceeding the primitive elastic limit. Neither of these, nor the later experiments of Bauschinger (1873) and others, led to the discovery of the elevation of the normal parabolic curve of successive elastic limits, *per saltum*, as finally discovered by the writer, and corroborated by Beardslee; but the increased stiffness noted was attributed to that general, normal, and invariably regular, elevation of the limit by increasing strain, which is seen in all cases and with all materials, and which produces a smooth and usually parabolic strain-diagram.

The writer has now noted and brought to the attention of engineers the fact that the exaltation of the normal elastic limit due to any given degree of distortion in the "iron-class," and its depression in the "tin-class," occurs under intermitted strain, whether the stress be applied longitudinally, transversely, or by torsion, and has presented experimental data proving this phenomenon to thus occur, and experimental quantitative determinations of the law of its variation with time, and the amount of such variation.

He has now to present still another interesting and probably important phenomenon of similar character.

It seemed probable that, if strain in either direction, when exceeding the elastic limit, always produces variation of the normal position of that limit, this effect must be due to a general modification of molecular relations, that should modify the effect of the force of cohesion in other directions than that in which the strain had been given. An investigation was made, and this matter was experimentally studied, as opportunity permitted, in the Mechanical Laboratory of the Stevens Institute of Technology, until sufficient data was accumulated to give conclusive determinations.

Iron and steel wires broken by tension were found to have the transverse elastic limit abnormally elevated, and to have become very stiff and of comparatively slight ductility. This was true of wires of other metals, and of heavier sections of metal. A large quantity of cold-rolled shafting of all sizes, of which both the longitudinal and the transverse dimensions had been altered by rolling cold, exhibited great increase of stiffness and strength, and an even more considerable exaltation of the normal elastic limit. Torsion similarly stiffened wires and rods longitudinally, and test pieces longitudinally strained, become stiffer against torsionally and transversely applied stress. Thus, orthogonal strains mutually affect orthogonal resistance of metals; and the engineer is, by this fact, compelled to study these mutual influences in designing structures in which the stresses approach or exceed, separately, or in combination, the normal *primitive* elastic limit of his material.

The following is, in detail, an account of the behavior of a bar of "good merchant iron," under the action of intermittent and successively applied orthogonal strain (transverse succeeded by tension):

A bar of good bridge or cable iron 2 inches square and about 4 feet long was split longitudinally; one-half was cut into tension test pieces, and the other half bent on the transverse testing machine to an angle at the middle of about 120 degrees; the bent bar was then cut into tension test pieces like the first, and finally all these pieces were broken in tension.

On examining the results thus obtained it was found that the original elastic limit of the metal, as exhibited by the test of the unbent bar, had been exalted by transverse strain in all parts of the bar which had been so strained before being tested by tension. This elevation of the primitive normal limit had not occurred, as would have been expected, to the greatest extent at the points most strained—*i. e.*, nearest the bend at the middle of the strained bar—

and less and less as the point of maximum strain was departed from, until, at the ends of the bar, this elevation became much less observable; but it took place irregularly, and, on the average, about as much at one part as at another.

The following are the figures obtained (the bent bar was cut into eight and the unbent into six pieces, and numbered consecutively from end to end):

I.—Effect of Transverse Strain on the Tensile Elastic Limit.

(Elastic limit in pounds per square inch, and kilograms per square millimeter.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per sq. m.m.	Lbs. per sq. in.		Kg. per sq. m.m.	Lbs. per sq. in.
No. 1	16.3	23 300	No. 1^1	21.6	30 900
" 2	16.7	23 800	" 2^1	23.5	33 500
" 3	16.9	24 100	" 3^1	18.2	26 000
" 4	16.4	23 400	" 4^1	19.6	28 000
" 5	14.6	20 800	" 5^1	22.4	32 000
" 6	15.7	22 400	" 6^1	19.6	28 000
			" 7^1	22 4	32 000
			" 8^1	19.8	28 200
Average	16.1	22 967	Average	20.9	29 825

The elevation of the primitive elastic limit, in this instance, is thus seen to have been 30 per cent., as an average, and in some parts of the bar about 50 per cent. The new series of the elastic limits are seen to be less uniform in value than in the original bar; but, comparing adjacent pieces, in no case is the elevation of the limit less than 1 ton on the square inch, and it usually amounts to more than double that figure. Singularly, also, the greatest change has been produced farthest from the middle, and the least at that point (Nos. 1 and 6, at the ends of the unbent bar, correspond to 1 and 8 of the other; and 3 and 4 of the first and 4 and 5 of the latter correspond, both pairs being from the middle). It should be observed that the quality of the bar tested, although good as metal of that size runs in the market, is not high, and is not as regular as it should be. It is a "50,000 pound iron."

But the transverse strain here produced, and which is seen to have so greatly modified the primitive elastic limit of the metal, had not materially or even observably affected its ultimate tenacity; this is seen by a comparison of the results of tests *to* the point of fracture, thus:

II.—Effect of Transverse Strain on Ultimate Tenacity.

(Tenacity in pounds per square inch, and kilograms per square millimeter.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per sq. m.m.	Lbs. per sq. in.		Kg. per sq. m.m.	Lbs. per sq. in.
No. 1	40.9	58 450	No. 1^1	34.1	48 700
" 2	34.5	49 330	" 2^1	34.7	49 500
" 3	35.4	50 520	" 3^1	33.5	47 900
" 4	35.6	50 980	" 4^1	37.5	53 600
" 5	36.8	52 540	" 5^1	36.4	52 000
" 6	30.1	42 980	" 6^1	36.8	52 600
			" 7^1	36.2	51 700
			" 8^1	33.4	47 700
Average	35.6	50 800	Average	35.3	50 475

It is seen that the two averages are as nearly identical in value as could be expected, and that the average ultimate resistance to rupture was apparently not altered by the straining due to transverse stress.

Yet, noting the difference of the figures for adjacent parts of the two stripes into which the original bar was split, we may make an interesting comparison, thus:

(We compare No. 3 with No. 4_1 and No. 4 with 5_1, because the middle of the bar falls, in the one case, between 3 and 4, and in the other, between 4_1 and 5_1.)

On examination of these figures we are struck by their irregularity, by the fact that the greatest changes both of elastic limit and of tenacity are produced at the ends of the bar, and by the singular phenomenon of an apparent *decrease* of tenacity at one of the ends of the bar. It seems improbable, however, that the latter effect can have been consequent upon any deformation of the bar; it may be more probably attributable to local defect in that end of the strained strip, due to cinder streaks. From the irregularity noted it seems evident that good iron, so called, may possess—as indeed inspection usually indicates—great local defects.

III.—Effect of Transverse Strain in Elevating the Primitive Elastic Limit and Ultimate Tenacity.

(Differences by comparing Tables I and II.)

	Elevation of Elastic Limit.		Increase of Ultimate Tenacity.	
	Kg. per sq. m. m.	Lbs. per sq. inch.	Kg. per sq. m. m.	Lbs. per sq. inch.
No. 1^1 No. 1	5.3	+ 7 600	− 6.8	− 9 700
" 2^1 " 1	4 1	+10 200	− 6.3	− 8 950
" 3^1 " 2	1.6	+ 2 200	− 1.0	− 1 430
" 4^1 " 3	2.2	+ 3 900	2..2	+ 3 080
" 5^1 " 4	6.0	+ 8 600	0.7	+ 1 020
" 6^1 " 5	5.0	+ 7 200	0.1	+ 160
" 7^1 " 6	6.7	+ 9 600	6.1	+ 8 720
" 8^1 " 6	4.1	+ 5 800	3.3	+ 4 720

Again, bars of iron were subjected to severe lateral compression, increasing their length and decreasing their cross section about 15 per cent.; then testing the metal by longitudinal strain, *i. e.*, by orthogonal stress, the writer obtained the following average figures. (See table below.)

Thus it is seen that lateral compression to this moderate extent may elevate the longitudinal elastic limit nearly 100 per cent., may increase the longitudinal tenacity 33 per cent., and may raise the modulus of elasticity 4 per cent., while decreasing the ductility in the orthogonal direction 60 per cent.

Tests by Tension after Lateral Compression.

Elastic Limit.		Tenacity per Unit of Area.				Extension.	Modulus of Elasticity.
		Original Section.		Fractured Area.			
Lbs. on sq. inch.	Kg. per sq. m.m.	Lbs. per sq. in.	Kg. per sq. m.m.	Llbs. per sq. in.	Kg. per Sq m.m.	Per cent.	Lbs. on sq. inch.
Unstrained bar...30 000	21	52 500	36.5	89 870	64	24.6	25 270 750
Strained bar 59 000	42	69 000	49.	105 600	75	10.4	26 230 500

A similar experimental determination of the effect of equal lateral compression on resistance to flexure gave the following figures:

FLEXURE AFTER LATERAL COMPRESSION.

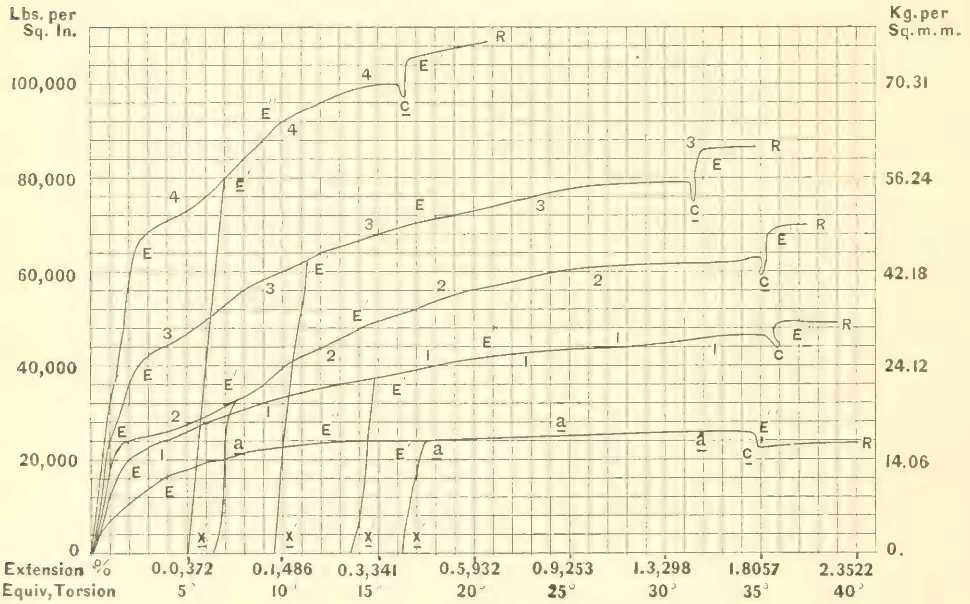
Cylindrical Bars 1⅛ in. diameter x 40 in. between supports (2.8 c. m. x 1 m.)

	Load at Elastic Limit.		Modulus Elasticity.	Max Load.		Resilience at Max. Deflection.	
	Lbs.	Kilog.	Lbs. per sq. inch.	Lbs.	Kilog.	Ft. Lbs.	Kg. m.
Unstrained bar	1217	553	27 174 500	1870	850	552	76.5
Strained bar	2700	1227	25 691 500	3395	1543	1049	145.

Thus lateral compression to the extent here practiced increased the elastic limit in flexure more than 100 per cent., *reduces* the modulus of elasticity as estimated from flexure 6 per cent., increases the maximum resistance 90 per cent., and nearly doubles the resilience at maximum deflection (4 in. 0.1^{m}).

From the fact that the changes produced by cross-bending are felt in internal strain ocurring, not simply near the point of flexure, but throughout the

FAC-SIMILE AUTOGRAPHIC STRAIN DIAGRAMS.



whole extent of the beam flexed, it would seem that shearing strains are more serious and general than we have hitherto supposed. This latter is a matter of importance in determining a correct theory of transverse strain, and the subject is undoubtedly deserving of extended and careful investigation with a view to discovering precisely the nature and intensity of such strains under all usual conditions in all the materials of engineering construction—first feeling out these strains in the manner here indicated, and then work

ing up the details of the theory until a complete and satisfactory analyses is attained.

Conclusions.—We may now summarize the results of the study of this subject, so far as the writer has yet presented them, and the conclusions to which he has been conducted.

In the annexed figure, let 1 1 1 1 represent the strain-diagram of a soft, malleable (wrought) iron, like Swedish or Norway; let 2 2 2 2 be that of a good common merchant iron of small size; let 3 3 3 3 be the diagram of a mild, and 4 4 4 4 that of a tool steel; while, in contrast to these examples of the "iron-class," let *a a a a* be the strain-diagram of a metal of the "tin-class;" for example, a ductile brass or bronze.

When these metals are strained, they are always found to exhibit a gradually increasing resistance pretty nearly proportional to the extent of change of shape, until a point, E, is reached, when the rate of increase of extension becomes greater—usually very much greater—and the deformation remains permanent when the piece is unloaded, and very nearly equal to the distortion under the load. The removal of the load then, if it is not renewed, gives a strain-diagram O, E, E_{I}, x_1, the distortion being permanent at x_1. This is the natural or "normal" curve, and it exhibits the normal and long known form of elevation of elastic limit. At the last moment, when the load and distortion are measured by the ordinate and the abscissa, respectively, of the point E_{I}, the elastic limit has become a maximum. Had the piece strained broken at E_{I} the limit of its elasticity would have become identical with the limit of strength and point of rupture, and its measure would have become identical with the modulus of rupture; for, considering the piece as unbroken at this point, the distorted piece would have for its strain-diagram the straight line E_{I}, x_1, and would have now been broken when loaded, at the moment that the stress attained the magnitude measured by the vertical let fall from E_{I} to the base line. The point E on each diagram marks what is usually known as the Elastic Limit. To distinguish this from the successive limits of elasticity which are due to permanent successively increasing strains, the writer has called the natural and original apparent limit of elasticity, E, the "*Primitive Elastic Limit*," and any other points, E_{I}, E_{II}, in a smooth curve representing a strain-diagram exhibiting the effect produced by unintermitted and regular distortion, the "*Normal Elastic Limit*" of the piece when in such condition of deformation, the whole curve being, as has been stated, a "*Curve of the Loci of successive Elastic Limits.*"

This normal elevation of the elastic limit, therefore, as strain progresses and permanent deformation increases, occurs regularly, and the strain-diagram takes the form of a smooth curve such as has been long known to represent it, and such as will be found in Morin's "Resistance des Matériaux" and other works published during the last quarter century.

But, instead of producing a regularly increasing deformation by regularly increasing stress, let load be steadily added until at some point E_{III}, corresponding to a distortion O, E_{III}, further addition of load ceases, and the piece remains permanently distorted. The metal now gradually yields, and there occurs a depression, *c*, of the elastic limit, which in the iron-class soon reaches a limit, but in the tin-class, if the load be not wholly or partly removed, may continue until rupture or maximum possible deformation takes place. Now, renewing the stress, it is invariably observed that this depression of elasticity is, in the case of the iron-class, only apparent; for the extension of the strain-diagram now takes place at a higher range, E_{III} R, and we observe at E_{III} that phenomenon of "Exaltation of the Normal Elastic Limits" which has been studied by the writer, as seen at E_{III} in curves 1, 2, 3 and 4, and which has until recently been unnoticed by authorities.

Making the same experiment on metals of the tin-class, we usually observe the depression of the normal succession of elastic limits which distinguishes this class from the first, as at E_{III} in *a a a a*, sometimes, however, this depression is unobservable.

This distiction between the two kinds of metals has been shown to have peculiar importance in its bearing upon the permissible values of the factor of safety in structures of metal, the value allowable in constructing in iron or steel being

lower, and that demanded in parts composed of the second class of metals being higher than would be proper except for this singular characteristic.

Studying the effect of rapidity of distortion, we find that in the case of the iron-class greater rapidity of distortion causes a decreased resistance, and that a slowly produced deformation causes relatively higher resistance, while the opposite is the case with metals of the second-class. We see that the rate of set is also related to the time allowed for it. It thus happens that with the same metals strained at such a rate as to give a strain-diagram **1 1 1 1**, an accelerated distortion may produce the diagram 2 2 2 2 or the diagram *a a a a*, accordingly as the metal is of the first or second class.

Still further, it has been shown in the earlier part of this paper that the exaltation of the elastic limit in iron, &c., is not confined to the direction of the strain produced, but that it affects the metal in such manner as to give it an exalted elastic limit with respect to all subsequent strains however applied. Thus, the engineer may make use of any method of strain that he desires, or that he may find convenient, to secure the condition of increased stiffness that he may desire in any given direction. He may strain his bars in tension to secure stiffness in either tension, compression or transversely, or he may give his bars a transverse set to obtain a higher elasticity in all orthogonal directions, or he may compress the metal, as by cold-rolling, and thus secure enhanced stiffness and elasticity in either longitudinal or transverse directions.

Finally, the writer having shown that the exalted elastic limit being a permanent and determinable effect of any strain which exceeds the "primitive elastic limit," it must remain a permanent and ineffacable record of the maximum load borne by the metal; this fact is seen to be of inestimable importance, as it enables the engineer to trace such distribution of strain as may have occurred in a wrecked structure, to determine the location of defective and flawed pieces, and to ascertain the distribution of strains generally, whether in structures or in single members.

This last suggestion may, perhaps, prove of more value to the profession than that relating to the increased safety due to this exaltation of the normal limit of elasticity. The value of this method of investigating experimentally the distribution of stress with a view to determining a correct theory of resistance of materials and of stress, is also probably obvious to every student of the imperfect and largely hypothetical mathematical method of treatment of the subject now usual.

These practical, readily applicable and exceptionably important facts, seen to be derivable from a careful and intelligent study of the position and of the method and extent of Variation of the Elastic Limit in metal, whether in single masses exposed to strain, or in structures, lend full confirmation to the remarks of the writer before the American Society of Civil Engineers, when first presenting this need of studying the elastic limit more carefully even than the ultimate resistance of metal.

"In determining the value of materials of construction, it is usually more necessary to ascertain the position of the limit of elasticity and the behavior of the metal within that limit, than to determine ultimate strength, or except, perhaps, for machinery, even the resilience. The fact is becoming recognized that it should be possible to test every piece of material which goes into an important structure, and *to then use it* with confidence that it has been proven to be capable of carrying its load with a sufficient and known margin of safety. . . . The method here described" (by use of the Autographic Testing Machine) "allows of this practice with perfect safety. The limit of elasticity occurs within the first two or three degrees, and as seen, the standard specimen may be twisted a hundred or even sometimes two hundred times as far without even reaching its maximum resistance, and often far more than this before actual fracture commences. It is perfectly safe, therefore, to test, for example, a bridge rod up to its elastic limit, and then to place it in the structure with a certainty that its capacity for bearing strain without injury has been determined, and that formerly existing internal strain has been relieved. The autographic record of the test would be

filed away and could at any time be produced in court as evidence—like the 'indicator diagram' of a steam engine—should any question arise as to the liability of the builder for any accident, or as to the good faith displayed in fulfilling the terms of his contract."

We now see that beyond all this lies open to the engineer a wide and important field of study, and that in the knowledge attainable by an investigation of the characteristics of the metal used in construction, as revealed to him by its behavior far within the limit of final or even incipient rupture, and as pictured in the strain diagram, he may find precisely that knowledge which is most essential to him where either economy or safety is of primary importance.

The subject is only just beginning to secure the attention that its importance demands, but it is to be hoped and fully anticipated that we may soon learn much more in relation to it, and that engineers will ere long make daily application of facts now discovered and of methods already made familiar to them.

IRRIGATION IN CEYLON.

By HENRY BYRNE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

The circumstances of Ceylon, as regards the benefits of irrigation and the methods of practising it, are so similar to those of India, that, in view of how thoroughly the subject has been treated in the papers relating to Indian irrigation in the Proceedings, some apology is needed for any remarks in reference to the smaller of the two countries.

Three different methods of obtaining water for irrigation are practised in the Island: 1st. Raising it by manual labor from wells and ponds; 2nd. Collecting it in tanks fed by the drainage of the neighborhood; and 3rd. Tapping the mountain streams and torrents.

The first of these is adopted in the small densely-peopled district at the extreme north of the island, known as the Jaffna Peninsula, and in a few other places where the country is so uniformly flat as to present no site for tanks of the ordinary Indian type, and where there is no river or other natural source of fresh-water supply but the direct one of the periodical rains. Garden cultivation is, however, the only one to which the system of irrigation from wells is applicable; because it alone is sufficiently profitable to pay for the labor involved, and because less water is required for it than for the cultivation of rice. Rice is certainly grown in the district, but to a very small extent, and only where the lands are unfit for other purposes; for a successful rice harvest there depends upon the rainfall, which is very uncertain, and upon the ponds, which often fail, but which, when full, yield a supply of water in aid of the rains. The water is raised from these ponds by a scoop swung from a rude scaffolding, and worked by two, four, or six men. The country lies at a level generally less than 10 feet above the sea. The wells are sunk to a depth of 15 or 20 feet through the magnesian limestone, which almost everywhere underlies the soil within 2 or 3 feet of the surface; and, except for a few days in the year when heavy rain falls, they are supplied by percolation from the sea, the water being freed from salt by contact with the limestone and other mineral substances in its slow passage to the wells. As may be readily supposed, wells thus filled are soon emptied; and in fact the supply is generally exhausted when a well has been drawn upon for a few hours; and from twelve to sixteen hours elapse before the supply is renewed. The mode of raising the water is by a lever, 20 to 30 feet in length, turning on an axle resting on two uprights, and having a bucket suspended by a rope or light pole from one end, which is lowered and raised by hand, the lever being weighted at the other end so as to counterbalance the filled bucket and facilitate the raising of it. When the well is deep and the lever long in proportion, the work is further aided by a man, and in some

cases two men, walking backwards and forwards on the lever, so as to contribute by their weight at the two ends alternately to the rapid rise and fall of the bucket. In this way about 600 cubic feet of water may easily be raised from a single well in one hour. On an average one well is sufficient for the irrigation of an acre of garden land in the driest weather where the soil is light, and of an acre and a quarter where the soil is less absorbent. As these wells never fail, being supplied from a source which is independent of rainfall, the successful raising of two, and even three crops, in the year from the same land is as much a matter of certainty as the recurrence of the seasons.

Those parts of the country where the system of tank irrigation prevails surround the district lying within what is called the Mountain Zone, and extend to within a few miles of the coast, embracing about three fourths of the area of the island, and having an elevation of from 20 to 100 feet above the sea. For the most part the rivers intersecting these low-lying districts are dry for ten or eleven months in the year; but in January and June, when heavy rains fall, they overflow their banks, and inundate a wide stretch of country on each side. In a few instances only was any attempt made in former times to utilize them as feeders of tanks, by throwing weirs across them in order to divert the water by canals to the desired storage ground. The general practice was to depend for the filling of each tank upon the rainfall within the limited area selected as the site for it. As the country is undulating, it affords thousands of sites where tanks could be formed by damming up the outlets of drainage basins. The early conquerors of the island, who (about five centuries before the Christian era) introduced into it the arts then known in India, recognized these natural advantages, and availed themselves of them—as did their successors for more than a thousand years—to cover the face of the country with tanks, mostly of large size, some few forming lakes of from 20 to 50 square miles in extent, having embankments or "bunds" of 10 to 15 miles in length, and capable of irrigating tracts of land as large as Middlesex. All were constructed on the same model, made familiar by the papers on Indian irrigation read before the Institution from time to time, an earthen embankment being made across the lower end of a drainage basin, such embankment being pitched on the upper side with rough stone, and having at one end or at both ends an overfall for the discharge of flood waters, and sluices of elaborate construction for distributing the water to the fields below.

But all these great works were destroyed in succession, perhaps soon after their construction, owing to inadequate provision in the length of the overflow, and to the difference in height between it and the bund, to meet the case of an extraordinary flood. This need not be a matter for surprise; for, even had the designers of these tanks possessed that knowledge of hydraulics which would have enabled them to adjust the length of an overflow to the discharge of a given body of water in a given time, they had no means of ascertaining the quantity to be discharged. The rain gauge was unknown to them; and it is certain that the country was then covered, as it still is, with a jungle so impenetrable that nothing more could be known than the bare fact, that by throwing an embankment across the low land between two hills of moderate elevation, a reservoir might be formed of capacity presumably large enough for the purpose intended. Only those perhaps who, like the author, have had occasion to lay out works of this kind in such a country, can form an adequate conception of the difficulty of arriving at data sufficiently reliable for the design of such a bund and overfall as would be safe under all circumstances. There are no maps, like the ordnance maps of Great Britain, from which the area of any drainage basin can be ascertained; and the cost and labor of making a special survey for the purpose in any given case would be enormous. Then, observations of rainfall have not extended over a sufficiently long period to show what ought to be taken into account in designing works of this nature; nor have they, owing to the want of intelligent observers, been carried out in all the most desirable localities. Thus, a rainfall 10 or 12 inches in

depth in one day—a thing of almost annual occurrence in some locality or another—had till lately been commonly accepted as the limit of what was probable anywhere; but in 1872 there was registered at one station a fall of 18.9 inches, and at another a fall of 17.9 inches, in twenty-four hours.

In view then of the difficulty of obtaining correct information on the two essential points of area and rainfall, it would almost seem that no work of this kind can be safe for any considerable length of time, unless the dam to retain the water be of masonry throughout, so as to form one continuous overfall from end to end; or, at least, the usual condition of things being reversed, and the length of the overfall, instead of being the smaller, be made by much the larger fraction of the whole length of the structure. The author's impression to this effect has been strengthened by what occurred recently to several tanks of moderate size in the eastern province of the island, restored or reconstructed only a few years ago, on designs based upon calculations which were believed to be perfectly safe. In the case of one of them, which may be taken as a fair sample of all, the overfall was of extraordinary length as compared with the bund, and it was believed that not more than 2½ feet depth of water could ever rise over it, while the top of the bund was from 6 to 7 feet above the estimated flood level. It seemed to the author, who saw it several years ago, that the great length of the overfall afforded ample provision against all possible accidents. But in January, 1878, the rainfall throughout the district was heavier than had been experienced for many years, giving rise to floods which carried away numbers of bridges and other works, and raising the level of the water in this particular tank to nearly 9 feet above the overfall, or just sufficient to overtop the bund and carry away a large portion of it.

Smaller tanks adapted for the irrigation of from 20 to 200 acres, which are most numerous in the northern and north-central provinces, and are the only structures of the kind now in use there, were formed in a much ruder manner than that followed in constructing the magnificent works which have fallen to ruin. They probably owe their existence to the small village communities, into which the population was divided on the failure and abandonment of the larger tanks, and when the country no longer possessed to any extent the skilled labor which the native kings had called into play when carrying out those immense works. In none of the hundreds of tanks which have come under the author's observation was there, until quite lately, anything deserving to be called a work of art. The overfalls were, in most cases, merely a depression in the bund, protected sometimes by rough stone pitching, or they were scarped out of the hard ground against which the bund abutted; while the sluices were formed of undressed blocks or slabs of stone, and often merely of rough timber, without any better means of stopping the flow of water through them than a gate of wattles banked up with turf, which the cultivators removed when they desired to let the water through. That structures so rude should have lasted through so many ages, can be due only to the ease with which any damage to them might be made good by the villagers. But neglect on their part has so often led to damage beyond their power to repair, resulting in the stoppage of cultivation for two or three years in succession, that the Government, in the interests of the people as well as of the revenue, felt bound to step in by legislation which placed the management of these tanks, and of small irrigation works generally, on a proper footing, and removed all excuse for that neglect into which they were gradually falling. Under this improved system, small works of restoration and repair are now carried out in all parts of the country, with skilled labor employed under Government supervision, and with a happier result than would probably have followed the realization of those grand schemes, so often proposed, of restoring the larger works abandoned centuries ago, to bring which into operation would necessitate the introduction of a new population.

Of the exceptional class of works already alluded to, where the design was to dam up the water of a river and divert it by a channel to a tank, the most remarkable is the Giant's tank, in

the northern province, of the date of construction of which there is not even a tradition. In this case, the mistake committed was more unaccountable than that which caused the destruction of the ancient tanks; for the nature of the country in which it is situated must have been easy to study, being a dead flat and generally open, the soil being incapable of supporting the luxuriant growth of jungle which renders other districts so difficult to explore. The dam, or "anicut," across the river was formed of large rectangular blocks of roughly-dressed stone, so well put together that it is still in as good order as when it left the masons' hands. The tank on the right bank of the river, some few miles below the anicut, formed by an earthen bund several miles in length, but nowhere more than about 10 feet high, was nearly completed, and a similar tank on the opposite bank in part constructed, before it was discovered that the bed of each was at too high a level for the water to reach it; and that both tanks, even had it been possible to fill them, must have been so shallow, that evaporation would not have left in them a month's supply of water for the area designed to be irrigated.

In the district of Karetchi, near the neck of the Jaffna Peninsula, the rice fields lie in several large patches on each side of one of those rivers which flow only at intervals when there is heavy rain. Like the fields in the peninsula, they are mainly dependent upon the direct rainfall, and upon the ponds which lie scattered amongst them. Although it was ascertained, by a survey which the author made in 1858, that a tank sufficiently large to irrigate them abundantly might easily be formed a few miles higher up, it was not considered that the work would be remunerative, in view of the cheap rate at which rice could be imported from India; and the project of carrying out the work was therefore abandoned. But the people endeavor to supplement the scanty supply of water derived from the rains, by throwing out temporary groynes of timber and earth from each bank of the river just before an expected flood, to divert a portion of the flood waters by channels leading directly to their fields. When the floods are moderate these groynes do a good service for a few weeks; but as often as not they are carried away. To check the tendency to erosion, by diminishing the velocity of water in them, the channels are made so tortuous, that their actual length is more than double what they would be if straight, and they are otherwise so badly formed that much of the small supply of water yielded by the river is wasted.

The third method of obtaining irrigation is practised in the mountainous districts by tapping the streams. The fields are numerous, but nowhere so extensive as those commonly met with in the low country. For the largest of them a channel six feet wide and about two feet deep, conveys all the water necessary for thorough irrigation; and to divert along it as much water as may be required, nothing more is needed in most cases, than to throw a few boulders into the stream just below the point from which the channel commences. In those few cases where, during dry weather, it is necessary to prevent any waste of the water brought down by the stream, there are properly constructed stone dams with regulating sluices. The channels are scarped out of the hillside, following the contour of the ground, and for a short distance after leaving the stream they are protected by a low wall on one side, which acts as an overfall whenever an undue quantity of water is discharged into them, as happens when the rains swell each stream into a torrent.

None of the irrigation channels in Ceylon are large enough to be used for inland navigation; and for this reason they have been everywhere laid out with as great a rate of fall as is consistent with a view to safety against silting. For the most part their inclination gives a velocity of water of from two to three feet per second; but even where the velocity reaches four feet per second, as it often does, there is no appreciable erosion of the sides or bed. Much, of course, depends upon the character of the soil through which the channel may be cut. But, so far as the Author's experience goes, the lightest soil will bear a velocity of two feet per second, where the sides of the channel have a slope of two to one; while in stiff clay soils, a slope of even one to one is ample in the most rapid of these channels. Such an

assertion may, no doubt, appear inconsistent with what is commonly set down in printed rules and tables as to the moving power of water at given velocities; but these rules, however valuable as a general guide, are based upon experiments tried under conditions which never, or but rarely, prevail in actual practice. The Author has generally found that silting (in the case of channels cut on a contour line in sidelong ground) is due not to the diminished velocity of the stream, but to the surface drainage from the land on the upper side of the channel. Yet even here the close vegetation above is usually sufficient to prevent the surface soil from being carried into the channel; and in the worst conceivable case, where the land above is bare and the soil loose, a catchwater drain above the channel, with frequent outlets under it, would be an effectual protection.

In no case has the Author found any tendency to the excessive growth of weeds in channels having an appreciable fall. It is in canals intended for navigation only, and where there is no current, that he has experienced any trouble in keeping down such vegetation; and a little attention on the part of the native overseers is sufficient for this. A small force of men is usually kept on a line of canal to prevent cattle from injuring the banks; and these men are provided with rakes, by which the weeds can be torn up and drawn to the banks as fast as they appear. Moreover, it is only in shallow canals used for flat-bottomed boats, where the depth of water never exceeds four feet in dry weather, that weeds are likely to spring up to any extent; and in these men can easily wade while working the rakes, if the canal be too wide for the weeds to be reached from the bank. The experiment of attaching large rakes to the stern of a boat drawn along a canal, in the hope of economizing labor by a wholesale system of weeding, had a fair trial; but the primitive method of raking by hand was found to be as efficient, and much more economical.

The Author regrets that he cannot give any details of cost of the various irrigation works undertaken in Ceylon in recent times. Such details would be of little interest, except in connection with a statement of results as to the quantity of water made available, and the extent of land brought under tillage in each case; and trustworthy information on these points is not procurable. Enough is known, however, to prove that in Ceylon generally, and especially in the unhealthy districts, where tank irrigation is chiefly carried on, the high price of labor must always render new works too costly to be commercially profitable. For this reason attention has of late years been confined to the improvement and restoration of small works long existing, but which had either been badly constructed originally, or had been suffered to fall into neglect, and where the cost of restoration, though often great for the small amount of work done, is trifling in comparison with the benefit obtained. By the outlay incurred, lands which had for many years lain fallow are now brought under cultivation; and the cultivators are no longer dependent for food upon imported grain, the price of which, however low at the sea-ports, is increased enormously by transport to the interior.

LIGHTHOUSE CHARACTERISTICS.

From "The Architect."

In March 1873 an article on "The Lighthouses of the Future" by Sir William Thomson, the Professor of Natural Philosophy in Glasgow University, was published in one of the periodicals. It suggested the introduction of a system of flashing resembling the Morse system employed in telegraphy, and the use of a uniform arrangement of bright lights, to be known from each other by the number and length of times they appear between intervals of darkness, instead of the existing fixed, revolving, flashing and colored lights. Each lighthouse was to be distinguished by a letter, and the light would appear in view, disappear, and reappear for a number of seconds that should correspond with the dashes

of the Morse alphabet. The plan by which the signals were to be carried out was simple. One large Argand lamp was to be fitted in the center of the light room, around it a metal band was to rise and fall with clock-work, obscuring the light at the proper intervals; or, secondly, a large spherical screen was to be moved round the lamp outside the great dioptric lenses, having slits in it from top to bottom, to allow the light to pass through at proper intervals, or by burning gas instead of oil, and lowering and raising the flame at the proper intervals by means of a water stop-cock, a small "by-pass" being connected to supply as much gas always as would prevent the flame from going out. The new scheme was not welcomed by sailors, and several masters of vessels testified that it was unsuited to the purposes of navigation, and fitted rather to bewilder than to help the mariner, especially in circumstances when the lights are of the most importance.

Sir William Thomson returned to the subject of lighthouses in December last, and in a letter to *The Times* advocated his threefold reform which consisted in (1) a great quickening of nearly all revolving lights; (2) the application of a group of dot-dash eclipses to every fixed light; and (3) the abolition of color as a distinction of lighthouse lights, except by showing dangers, channels, and ports, by red, and white and green sectors.

"My proposal" he wrote "is to distinguish every fixed light by a rapid group of two or three dot-dash eclipses, the shorter, or dot, of about half a second duration, and the dash three times as long as the dot, with intervals of light of about half a second between the eclipses of the group, and of five or six seconds between the groups, so that in no case should the period be more than 10 or 12 seconds. This proposal has been carried into effect with perfect success in Holywood Bank Light, Belfast Lough, now the leading light for ships entering the Lough, but which until 1874 was enclosed in a red glass lantern, and was only visible five miles, and was constantly liable to be mistaken for a sailing vessel's port side light entering or leaving the harbor of Belfast, or the crowded anchorage of Whitehouse Roads. In 1874 the red glass was removed, and the light was marked by dot, dot, dash (— — ——, or letter U), repeated every ten or twelve seconds, and has been so ever since. It is now recognized with absolute certainty, practically, as soon as seen in ordinary weather from the mouth of the Lough, ten miles off, and has proved most serviceable as leading light for ships bound for Belfast or entering the Lough. It is much to be desired that the dot-dash system should be seriously considered by the lighthouse authorities of our islands. Hitherto, when attention has been called to it, it has been dismissed with pleasantry, "Winking lights won't do," or else something utterly different has been gravely considered and justly condemned. Is it too much to hope that when the new Eddystone Lighthouse is finished the light shall not be, as hitherto, an undistinguished fixed light, but a fixed light distinguished by a group of dot-dash eclipses—such as dot, dash, dot (— —— — letter R)—which is particularly easily distinguished by its rhythmical character; and that the Needles Light, which shows red over a great area of sea south of it, and when distinguished, as at present, is liable to be inconveniently and even dangerously mistaken for a ship's port side light, shall have a distinctive dash, dot (—— — or letter M) given to it, which, whether in its red or on its white sectors, will instantly show it to be itself and no other light at sea or on shore? The five years' practical demonstration of the dot-dash system in Belfast Lough ought surely to weigh with the authorities. The introduction of a well-proved remedy for an admitted defect of our lighthouse system should not need that advocacy which moved the unjust judge, and the sea-faring world should not suffer the delay in gaining a great benefit which the strict following of that judge's precedent would entail."

The Committee of Lloyd's, immediately after the letter was published, wrote to the Board of Trade, stating that they considered Sir William Thomson's idea that each lighthouse should furnish some distinctive mark by which it may be recognized, and not confounded with any other, was well worthy of consideration. The Board of Trade accordingly formally brought the subject under consideration of the authorities having charge of lighthouses in England, Scotland, and Ireland,

and in due time reports were returned to the Board.

Messrs. D. & T. Stevenson, the engineers to the Board of Northern Lighthouses, in their report, say that the essential principle of the simple lighthouse characteristics at present in use is that of optical distinction and strongly marked, and therefore obvious differences in the periods of light and darkness, while the proposed system consists of intricate and minutely different numerical distinctions in number and order of eclipses crowded into very short periods.

The origin of such schemes as that of Professor Babbage and Sir William Thomson is, according to Messrs. Stevenson, an erroneous idea regarding facts which are well established. There is a current and widely diffused, though wholly unfounded notion, that the great cause of shipwrecks is the mistaking of one light for another by the mariner. Mr. Alan Stevenson, in 1851, showed by statistics of the Scotch coasts for four years that the real cause of shipwrecks at night was not the mistaking of one light for another, but rather the nonvisibility of the lights. Out of 203 shipwrecks occurring in these four years, 133 occurred by night, and in only *two* of of these was it ever alleged that the appearance of the light had not been recognized, and in only one of these two cases were the lights specified that were alleged to have been mistaken for each other, viz., the *revolving* light of Inchkeith for the *fixed* light of the Isle of May. The grand requisite of all sea lights is penetrative power, and not a great variety of characteristics; and they should be distinguished either by purely *optical* characteristics, *i.e.*, by appearances at once appreciable by the eye, or else by broadly marked *variations* of periods, and not by minute differences exhibited in rapid succession indicative of certain letters of the alphabet, which could only be read by people trained to such a system of telegraphy, or the modification of this system now proposed by Sir William Thomson. Messrs. Stevenson, in conclusion, say that the system of altering all fixed lights to the dot-dash, or Morse alphabet system, would, from the minute differences in characteristics, lead not only to perplexity in the mind of the sailor, but we fear to disastrous results; and that such a mode of distinction, though it were free from danger, is uncalled for, because unnecessary.

The Elder Brethren of the Trinity House also declined to recommend the adoption of the Morse alphabet as being superior to the methods now in use, or better adapted to the comphrehension of every grade of martime intelligence. It is believed, they say, that if each light of the whole cordon round the coast were taken *seriatim*, there is not one whose identification could not be secured by observations far rougher and less minute than would be required for determining the existence and the sequence of longs and shorts.

The Commissioners of Irish Lights were found to be less inimical to the new system than other authorities. It would be injudicious, they believe, to adopt the dot and dash system generally, but the group flashing system could be applied with advantage to those lighthouses on the Irish coasts by which the transatlantic vessels shape their courses. It would be of incalculable use to the masters that on first making land, either in dark or foggy weather, they should have an unmistakably defined light. The Commissioners point out the concurrence of opinion between their scientific adviser, Dr. Tyndall, and Sir William Thomson. Dr. Tyndall said that it would be easy to give every lighthouse supplied by gas so marked a character that a sailor should recognize it with infallible certainty, and in carrying out his recommendations the Commissioners were very early impressed by the extraordinary facility with which, by the simple turning on and off of gas at any required interval, distinctive variations, to almost any extent, might be made in lighthouse lights, without impairing in the slightest degree the great penetrative power of the light itself. So far back as 1867 they applied this system to Wicklow Head, where, by a very simple piece of clockwork, the light is turned on and off, so as to cause a light of ten seconds, and an interval of darkness of three seconds duration; and in 1871 at Mine Head the same principle was adopted with fifty seconds light and ten dark. The use of gas in other lighthouses was recommended, and in 1877, with the approbation of the Board of Trade, the Commissioners placed at the

new lighthouse at Galley Head a group flashing gas-light, which was lighted in the following year, and is now, they believe, the most striking example in the world of this kind of light, the flashes of the powerful quadriform revolving light at that station being broken up into groups producing an effect of unrivaled individuality. This system of group-flashing is capable of almost endless variations.

When so many experts are opposed to Sir William Thomson's system, there is not much chance of the introduction of the dot and dash flashes into lighthouses. But his other suggestions have been more successful. The advantage of colored lights at important points is no longer insisted on. Even Messrs. Stevenson acknowledge that the use of color is attended with disadvantage, not only to men who are color blind, but to all mariners in foggy weather, when the white lights acquire a reddish hue so as to simulate the effect produced by red shades.

ECONOMY IN ELECTRIC GENERATION.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

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THIS subject is one of no little importance at the present day of lightning speed. The scientific literature bearing on electricity has hard work to keep abreast with practical electricians. Instead of men now "thinking where others had but dreamed," they are acting where others had scarcely even dreamed. For instance, practical electricians have found that to generate a current economically is one thing, while to obtain a maximum current from a given source, is quite another. Many books on electricity treat of the latter, while very few if any make a special point of economy.

In what follows, batteries will be first considered, and subsequently mechanical generators.

In any electric circuit the energy is equal to the product of the electromotive force and current strength ; or, it is equal to the square of the electromotive force divided by the resistance; or, it is equal to the product of the resistance and square of the current strength. According to the last, if there be no resistance for a given current there will be no energy. But if there exists a certain resistance to the current, the resistance and current being constant, a certain definite number of foot pounds of energy per minute will be required to maintain the current. It appears to be immaterial as to where or what that resistance is, whether internal or external; that is, whether it be in the generator, external to it, or divided between them. In practice, however, it will usually be divided between them. If the generator be a given lot of equal battery elements, it has been determined that the *maximum* current, with given external resistance is obtained, when the batteries are so arranged that the internal resistance equals the external. But considering the energy required, as proportional to the whole resistance, it appears that in this case half the total energy is consumed in overcoming the internal resistance. If we could in some way reduce this internal resistance, and at the same time retain the same useful result, that is, the same current strength and external resistance; then, of course, that useful result would be secured with greater economy, or with a less expenditure of foot lbs. of energy; or in other words again, the electric generating apparatus would have a higher efficiency. This efficiency is stated only with reference to the useful result of working expenses, and not with any consideration of the first cost of apparatus. The latter will generally be increased as the efficiency is raised in the manner above named. There will therefore be a limit where the interest on the increased investment in first cost will offset the saving in working expenses.

As an example, let us investigate the case of electric generation with a lot of voltaic batteries. The form of battery

is immaterial to this investigation, whether it be Daniell's, Grove's, Bunsen's or other; but it will be convenient to assume that all the cells employed have the same working conditions, that is, that the electromotive force and internal resistance of all of them be the same, and remain constant. If, however, these conditions be different, some arrangement would be possible in each case, but the present problem is a general one in efficiency instead of a special one in the arrangement of a lot of heterogeneous battery elements.

Let N = total number of equal cells: $=nm$;
- n = number in each row, or in series;
- m = number of rows, or number in multiple arc;
- e = electromotive force of each single cell;
- r = internal resistance of each single cell;
- l = external resistance;
- E = electromotive force of whole battery;
- C = current strength of circuit;
- R = total resistance of circuit;
- z = zinc consumed.

To this case the well known law of Ohm applies, or

$$C = \frac{E}{R} = \frac{ne}{\frac{nr}{m}+l} = \frac{ne}{\frac{n^2r}{N}+l} \quad . \quad . \quad . \quad . \quad (1)$$

The equivalence of these expressions is readily perceived, from the fact that the total electromotive force is equal to the sum of the individual ones, e, in a series, and the fact that the internal resistance is equal to the sum nr, of one series, divided by the number m, of series, the total resistance being therefore $\frac{nr}{m}+l$. Also we may eliminate m, by aid of the equation $N=mn$.

Perhaps no better way of securing the present object can be devised than to take the maximum current of a given lot N, of cells for the given current, and then find the conditions, if any exist, for securing the same current more economically. To find the maximum current realizable from N cells by varying n and m, take C = the least expression of (1) and place the differential of C with respect to n equal o. We thus obtain the well-known relation for the arrangement, giving the maximum current from a given number of cells, viz:

$$n = \sqrt{\frac{Nl}{r}} \quad . \quad . \quad . \quad . \quad (2)$$

This placed in the expression $\frac{n^2r}{N}+l$, gives $2l$ for the total resistance of the current. This reiterates the well known fact that the maximum current is obtained from N cells when the arrangement in series and multiple arc is such that the internal resistance equals the external.

Applying the law of Joule, or its equivalent, to our battery circuit we have the

$$\text{current energy} = RC^2 = EC = \frac{E^2}{R} \quad . \quad (2')$$

where R is the total resistance. When the internal resistance is equal to the external, it appears that half the current energy is expended in overcoming useless internal resistance. The consumption of zinc being proportional to the energy of current, the amount of zinc required is here double what it would be if the internal resistance could be zero.

In seeking to economize zinc, we must in some way reduce the internal resistance. To do this, and at the same time maintain a constant current strength, it is plain that more than N cells will be required; because, for the number N, the given current is the maximum. But if economy of zinc follows from the addition of a few cells, it will be advisable to do so, and to what extent is determined, only, by comparing cost of battery cells as an investment with a saving in the running expenses. To ascertain the number of cells to add, let N, n, m and z, be changed to N′, n', m' and z'; other things remaining constant.

Then

$$C = \frac{n'e}{\frac{n'r}{m'}+l} = \frac{ne}{2l} = \frac{n'e}{\frac{n'm}{m'n}l+l} \quad . \quad . \quad . \quad (3)$$

the last expression being equivalent to the others, from the fact that for the maximum current above, we have

$$\frac{nr}{m} = l.$$

This gives

$$\frac{m}{m'}=2-\frac{n}{n'}, \ \& \ \frac{n}{n'}=2-\frac{m}{m'} \quad . \quad . \quad . \quad (4)$$

$$\frac{N}{N'}=\frac{mn}{m'n'}=\frac{m}{m'}\left(2-\frac{m}{m'}\right)=\frac{n}{n'}\left(2-\frac{n}{n'}\right) \quad . \quad (5)$$

$$\frac{m}{m'}=1\mp\sqrt{1-\frac{N}{N'}} \quad \frac{n}{n'}=1\pm\sqrt{1-\frac{N}{N'}} \quad . \quad (6)$$

$$\frac{z}{z'}=\frac{EC}{E'C}=\frac{neC}{n'eC}=\frac{n}{n'}=2-\frac{m}{m'} \quad . \quad . \quad . \quad (7)$$

The duplex signs in (6) indicate two arrangements, by which the equivalent current C may be realized when a certain number of cells have been added to that lot for which C is the maximum current. The arrangement obtained by using the upper sign in (6) economizes zinc, while the lower sign results in extravagance.

Equation (4) indicates that we may add until m' is infinite, in which case $n=2n'$. Also that by the other arrangement n' may be made infinite, for which $m=2m'$. The first is economical, and the last extravagant in zinc. These are the ultimate possible limits to which we can go by this method of procedure, that is, by finding the maximum current from a given number, N, of cells, and then adding to them for the purpose of securing the same current more economically. Of course we are not limited in this by the assumed current C, as evidenced by (1) and (3). Assuming C, we at once obtain, see eqs. (2), (3), &c.,

$$n=\frac{2Cl}{e} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$N=\frac{n^2r}{l} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$m=\frac{N}{n} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

for which C is the maximum current.

Example. In seeking help from a numerical example take

$$l=4., \quad r=1. \quad N=144.$$

Then $\quad n=\sqrt{\frac{Nl}{r}}=24, \ \& \ m=6$

for maximum current, which $=C=3e$.

Now suppose N be increased to $N'=192$, eq. (6) makes

$$\frac{m}{m'}=\tfrac{1}{2} \text{ or } \tfrac{3}{2} \ \& \ \frac{n}{n'}=\tfrac{3}{2} \text{ or } \tfrac{1}{2}.$$

or $\quad m'=12$ or 4 : & $n'=16$ or 48 :

$$\& \ \frac{z}{z'}=\tfrac{3}{2} \text{ or } \tfrac{1}{2} : \text{ or } z'=\tfrac{2}{3}z \text{ or } 2z$$

Hence in using the 144 cells in place of the 192, fifty per cent. more zinc will be required, for a given current worked a given time.

The relative quantities of zinc 1st for 144 cells, 2nd 192 economically, 3rd 192 extravagant, are as 3 : 2 : 6.

As another example take

$$m'=\infty, \ n=2n' \text{ and } z'=\frac{z}{2}$$

or $\quad n'=12$ and $C=3e$.

Again, if

$$n'=\infty \ \ m=2m' \text{ and } z'=\infty$$

or $\quad m'=3$.

The economical arrangement indicates that half the zinc is saved for the imaginary or impossible case where N' and m' equal infinity, instead of 144; whereas if it be 192 instead of 144, the saving is a third, and is a result entirely practicable.

This extended comparison commenced soon after eq. (1), of the arrangement for a maximum of current with other cases, has been made partly to show that there is a real distinction between problems for maximum current and economy of zinc, and that the problem of the books for maximum current should not be confounded with the one not in the books for minimum of zinc.

But the maximum current arrangement is not necessarily taken into account in studying the economy problem. For instance, in eq. (1) if N and $m=\infty$

$$C=\frac{n'e}{l} \quad . \quad . \quad . \quad . \quad . \quad (10).$$

If C is made same as before, $=3e$, and $l=4$, then $n'=3l=12$, which is the same value as previously found for $m=\infty$. Again, if $N=192$, and $C=3e$, then eq. (1) $n=16$ or 48 same as before found for 192 cells.

Equation (10) determines the minimum number of cells in series for a given current strength C, external resistance l, and individual electromotive force e, for the case of either an infinite number of cells, or of a zero internal resistance. Also if the internal resistance $r=o$, only one row of cells is required.

To make a general solution of the case

of a battery working with a current C, against an external resistance l, and reasonable internal resistance, as compared with a battery of like cells arranged with zero internal resistance, and working with like external conditions, we have

$$C=\frac{n'e}{l}=\frac{ne}{\frac{nr}{m}+l}=\frac{ne}{\frac{n^2r}{N}+l} \quad . \quad . \quad . \quad . \quad (11)$$

$$\frac{n}{n'}=\frac{nr}{ml}+1=\frac{n^2r}{Nl}+1 \quad . \quad . \quad . \quad . \quad (12)$$

$$\frac{z}{z'}=\frac{n\epsilon C}{n'\epsilon C}=\frac{n}{n'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13).$$

It appears from these that for zero internal resistance, the number of cells in series is proportional to the current C; also that in all cases, for a given current, &c., the consumption of zinc is simply proportional to the number of cells in series. This last corroborates eqs. (4) and (7), the first of which says that if $m'=\infty$ the current requires half as many cells in series as the same current when a maximum; while the second says, that when $m'=\infty$ the zinc consumption is reduced one half.

In Dynamo-electric and Magneto-electric machines will be found opportunity for applying the above principles and conclusions to some extent. The application which is most obvious, and at the same time most important, is that pertaining to the relative resistances, internal and external. From the fact that zinc consumed in batteries has a definite mechanical equivalent, or known value of foot lbs. of energy per lb. of zinc, it appears that the energy developed by a quantity of zinc in a battery may be treated quantitatively from its electrical effects, as well as the energy of a steam engine from its dynamo-electric effects. Though the exact relation in the latter is more complex than in the former, because of the varying nature of the internal resistance, yet that resistance, known or unknown, must stand in the same relation to the external resistance, as regards the foot lbs. of energy consumed for each, as has been above indicated for zinc consumed for each, in the case of batteries. Of course the foot lbs. here considered is that concerned in electrical effects, and exclusive of that consumed in overcoming resistance of mechanism. In magneto machines, where the magnetic field is maintained by permanent magnets, the internal resistance is less than in dynamo machines, because no portion of the circuit is included in coils of field electro magnets. This is favorable for the employment of permanent magnets.

In machines like the Wilde's, where the field magnets are excited by a supplementary, or exciting machine; the sum total of energy consumed, for a given external effect, is to be known in order to consideration of economy.

To this end let us suppose two machines put in comparison, giving the same current C, through the same external resistance L. In the first, or dynamo-electric machine, let the whole current have the circuit of armature and electro-field magnets whose resistances are R_1 and R respectively. Then the energy required to drive the machine, when in continuity of action, independent of the frictional resistances will be

$$\text{Driving energy}=C^2(R+R_1+L).$$

In the second let the exciting machine produce the same intensity of working magnetic field, with a field electro-magnet having the same volume of bobbin as in the first. This is perhaps fair because the first machine may have bobbins occupying all available room. Even then the second machine will be as large and expensive, independently of the exciting adjunct, as the first machine.

To maintain the same intensity of working field, we must have

$$I=NC=nc$$

where N is the number of turns of wire in first and n in the second of the main exciting bobbins; c being the exciting current in second, and produced by the exciting adjunct. The equation follows from the laws of electro-magnetic induction, making intensity of excited magnetism proportional to the number of turns of wire and to the current strength. Again, for equal volumes of bobbin the relation of the lengths will be that of the number of turns of wire, so that if S and s stand for sections of wire respectively, we have for equal volumes,

$$SN=sn$$

Again, the electrical resistance is pro-

portional to length and inversely as section giving

$$\frac{r}{R'}=\frac{S}{N},\ \frac{n}{s}=\frac{n^2}{N^2}=\frac{C^2}{c^2}$$

r_1 being the resistance of the main exciting bobbin in second machine. The continued equalities follow from combining the two preceding equations with last.

Lastly, if r_1 be the internal resistance of the exciting adjunct, we have the total energy consumed in the second arrangement, or machine, the adjunct being considered part of it,

$$\text{Driving energy}=C^2(R+L)+c^2(r+r_1)$$

the last term standing for the energy consumed in the adjunct, and bobbins of main field magnets. But by combining c^2r with the next equation preceding it becomes C^2R_1, which, substituted, gives for the last named

$$\text{Driving energy}=C^2(R+R_1+L)+c^2r_1$$

the same as found for the first machine with exception of the excess of last term.

From this it appears that the second arrangement is more extravagant than the first. To diminish the last term, c or r_1 must be made less. As to the latter, we are brought to the same conclusion for the adjunct as for the principal machine, viz: economy requires the internal resistance to be a minimum. To decrease c, it will be necessary to use finer wire on main field magnet with more turns. The resistance of this bobbin will then be increased, which will hinder the prejudicial interactive currents, reducing the sum total of resistance, and possibly giving a resultant advantage. The consequent internal resistance, increasing with speed, often making the running internal resistance much greater than for the machine at rest, amounts to a serious drawback in consumption of power, heating of machine, &c. It is only in this, therefore, that we can expect to find advantage in employing what has above been termed, for convenience, the adjunct.

But if this gain is not found sufficient to cause the last term in the last equation above to disappear, then the first machine has advantage over the second. Finally, in those machines where, as is often the case, only part of the main current C is sent through the main field electro-magnets, we will evidently have the

$$\begin{aligned}\text{Driving energy}&=C^2L+(C+c)^2R+c^2r\\&=C^2L+C^2R+2CcR+c^2R+C^2R_1\end{aligned}$$

since $c^2r=C^2R_1$ by comparing with an equation above. Hence,

$$\text{Driving energy}=C^2(R+R_1+L)+2CcR+c^2R$$

the energy apparently being in excess by the last two terms. In this arrangement the gain over the first above, where whole current is sent through main field electro-magnets, is to be looked for in diminished internal consequent resistance, to an extent sufficient to cancel the last two terms above.

THE FUTURE OF THE IRON TRADE.

From "The Engineer."

When the demand for English rails sprang up some nine months ago in the United States, and the iron masters of Great Britain became exceeding glad, we suggested that the Iron and Steel Institute should send over a deputation of two or three of its members to ascertain by personal investigation carried out in the United States, whether the enormous demand anticipated was or was not to be regarded as legitimate; whether it was or was not likely that the railways proposed would really be constructed; whether the demand was to be looked on as altogether abnormal and temporary, or as the natural outcome of the growing wealth of the New World. Our advice was not followed, but the demand for iron, in every shape and form, for the United States, attained proportions wholly unanticipated. It is not too much to say that some persons lost their heads and went mad for iron in any shape. Rails, pigs, bars, scrap, sheets, old rails, hoops, steel ingots, tires, came all alike. Nothing that could

be deemed iron or steel wanted a market. This was all very well up to a certain point; but unfortunately ironmasters believed that that which was but a passing wave was the rise of a tide, and they increased their powers of production enormously. In the United States precisely the same thing was done, and iron enough has been made in the last few months to satisfy the extra demands of the next year. The consequence is that iron returns to the price paid for it before the recent rage, and ironmasters find themselves with much money invested in new furnaces and plant for which they will never get a return. The events of the last nine months have been exceedingly instructive, however; and if only the lessons taught are taken to heart something will have been gained in return for an enormous outlay.

We learn, then, in the first place, that at no time in the future will it be possible permanently to raise the price of ordinary pig iron above 45s. per ton, or the price of steel rails above £6—probably we should be nearer the mark if we said £5. All calculations of profit and loss, wages, cost of coals, and so on, must be based on these figures, and estimates resting on prices higher than these will prove misleading. It may be a very unpleasant thing to be told that 40s. is likely to be a fair price for pig iron in the future, but the truth must be said, and should be accepted and acted upon. It is not difficult to see why the price must be kept somewhere about the figure we have named. The ironmaking plant of the civilized world is now much larger than it need be. No demand of at all a permanent character can exist which would tax all the blast furnaces of the world to supply it. To prove that this is true, we have only to possess ourselves of the fact that there is not now an iron-producing district of any importance in the world in which furnaces may not be seen which are out of blast. Not that they are out of order and therefore idle, but idle simply because there is no work for them to do. But the moment a demand springs up, all the previously idle plant is started; and the production of iron is enormously increased; and the market is glutted, and prices fall at once. It is absolutely necessary that at present a large proportion of the iron-making plant of the country should be idle. If it were at work, iron would of necessity be so cheap that it would not pay to make it. Furthermore, the tendency of every sudden wave of demand is to augment the quantity of permanent plant, and the larger the amount of plant standing idle the greater will be the tendency to sell iron cheap, because, if it be possible to make a blast furnace earn even 2 per cent. per annum clear profit on its first cost, by selling its pigs at 35s. a ton, the manufacturer will rather do so than let the furnace stand idle. Indeed, very many furnaces are now kept going which are not paying one halfpenny of interest on their cost, the whole of the pigs which they are producing being stocked on the chance that they may yet be sold at a fair profit. To illustrate the ease with which the iron-producing power of the world is augmented in reply to a sharp demand, we may say that in October, 1878, there were in the United States 708 furnaces, of which only 251 were in blast. At the end of the year this number had increased to 265; but at the end of 1879 there were 388 furnaces in blast, out of a total of 697 furnaces which were either in working order or admitting of being put in working order. The increase was thus 123 furnaces, and assuming that each would make a little over 400 tons a week—a very moderate estimate—the total augmentation would be 50,000 tons per week, or, taking forty-five working weeks in the year, 2,250,000 tons per annum. But there remain still 309 furnaces not at work. If we allow that 200 of them are so situated that they cannot be worked at a profit, and must be regarded as useless, we have still 109 furnaces left as a reserve ready to be blown in at short notice, and capable of making, say, 40,000 tons of iron a week, or 1,800,000 tons per annum. In 1879 the United States made 3,070,875 tons of pig iron, and it is beyond question that the rate of production increased continually during the year, as more and more plant was started. The result of all this production was that a demand, which extended over a couple of years, would have proved of the utmost service to iron-making districts, was all supplied, and much more than supplied, in a few

months, and the value of pig iron has fallen no less than £4 per ton in the United States. The facilities provided by steam for intercommunication are now so great that the moment a demand occurs for any article or commodity in one country several others can rush to supply it. Accordingly, although England is 3000 miles from America, the demand in the last named country stimulated the trade in Great Britain, and it may be safely estimated that in the last twelve months we have made 2,500,000 tons more pig iron than we did in the preceding year. Little or none of this extra quantity has been used in Great Britain, nor has it gone to the continent. America has absorbed the larger portion of it; and there can be no doubt that the United States have at the present moment a great deal more iron than they can possibly use, and facilities for producing at any time more iron they can want—always provided that the consumer does not insist on having supplied to him in any one year as much iron and steel as he can use in two years. Under the circumstances, we have no hesitation in saying that the prospects of the iron trade in Great Britain are so bad as to justify almost the worst that can be said of them—that is, if low prices mean bad trade. It has recently been urged that as there are firms in the North who are actually blowing more furnaces now, that the prospect for the future cannot be very bad. It is to be assumed, it is urged, that ironmakers know their own business, and that they would not increase their powers of production if they did not anticipate a good trade. Those who reason thus know but half the truth. They know that furnaces are blown in, but they do not know why. The truth is that the furnaces started are put in blast only to work off orders given long ago. Thus we could name a firm in the North which contracted some time ago to supply a very large quantity of a given kind of pig made in a special district. This firm are now making iron to stock, yet they have to start another furnace solely to comply with the terms of the contract; as the price is very good, not much harm is done. It will be found that in almost every case where plant is being increased peculiar conditions have dictated that increase.

As regards the future price of pig iron, it appears that that must be determined almost entirely by wages—not wages to the ironmaker alone, but wages to the collier and the ironstone miner. Plant exists in profusion. There is much more than enough of it, and if wages could be cut down sufficiently, then pig iron might be made at a profit for about £1 per ton. But it appears as though, both in this country and the United States, wages had been reduced almost as low as they can be got. There is nothing else to which the consumer can look just now for a chance of getting cheaper iron than a reduction in wages; and until this takes place iron will not fall much below its present value. After a time those now making iron to stock will find that they must stop, and furnace after furnace will be blown out both here and in the United States. But this step can very little affect the price of iron. Furnaces will not be blown out while they can be worked at any profit, and whatever is the number that may be kept in blast, it will be found not to be less than that required to keep pig as cheap as wages will let it be. All the signs of the times indicate a great contraction in the demand for iron from Great Britain, and the sooner the truth is realized the better. The following extract from the report of Mr. Swank, secretary to the American Iron and Steel Association, holds out little prospect of better times for us: "We may here remark that we regard the claim that 1,500,000 gross tons of rails will be required by the new and old railroads of the country in 1880, and that American works cannot meet this requirement, as unwarranted by past experience and existing probabilities. It is true that in 1872 we required about 1,366,830 gross tons—1,530,850 net tons —but since the close of that year we have laid over 2,000,000 gross tons of steel rails, the superior wearing qualities of which must be considered in estimating the probable quantity of rails to be required this year for renewals of existing tracks, while the mileage of new roads to be finished in 1880 is not likely to greatly exceed the average of the three years 1870, 1871, and 1872, which was 6466 miles. Hence it is not probable that we shall require as many rails in

1880 as in 1872, and those that are required can all be made by American works." It may be pointed out that as regards the rail trade, our only customers worth consideration, apart from the United States, were British India, Australia, Canada, and Brazil. In the first four months of this year we exported 67 per cent. more steel rails than we did in the corresponding period of 1879. Of our total rail exports, the United States took $32\frac{1}{2}$ per cent. against 1 per cent. last year; British India took 26.9 per cent.; Australia, 10.7 per cent.; British North America, 6.3 per cent.; Brazil, 4.1 per cent. The British colonies and the United States together took $78\frac{1}{2}$ per cent. of the total exports this year and $60\frac{1}{2}$ last year. The quantity taken by the colonies altogether has been 90,555 tons this year, against 70,613 last.

ON THE ROTATION REQUIRED FOR THE STABILITY OF AN ELONGATED PROJECTILE.

From Proceedings, Royal Artillery Institution.

By A. G. GREENHILL, M. A., Professor of Mathematics to the Advanced Class of Artillery Officers.

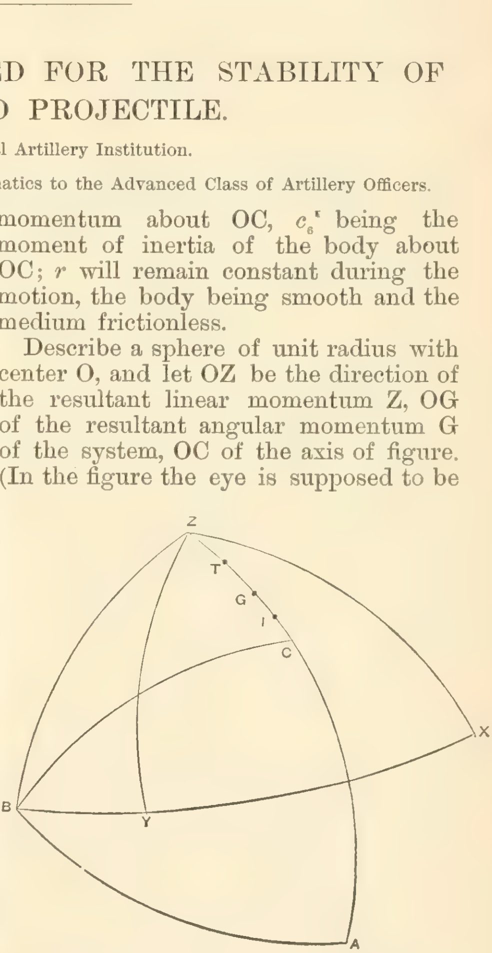
When a body moves in a medium it sets the medium in motion, and the inertia of the body—that is its resistance to change of motion—is no longer necessarily the same in all directions, as it would be in a vacuum.

Consider an elongated projectile of revolution moving in air under no forces, and let c_1 denote the inertia of the body to motion perpendicular to its principal axis, c_3 the inertia of the body to motion in the direction of that axis; then if u, w be the component velocities perpendicular to and in the direction of the axis, $c_1 u$ and $c_3 w$ will be the components of linear momentum in those directions respectively; and if no forces act on the body, $c_1 u$ and $c_3 w$ will have a resultant, Z suppose, fixed in magnitude and direction, by the principle of the conservation of linear momentum.

If O be the center of the body, and if p be the component angular velocity about an axis OA, perpendicular to the axis of figure, then this motion of the body will stir up the surrounding medium; and if $c_4 p$ be the component angular momentum about OA of the body and medium, then c_4 is called the effective moment of inertia of the body about an equatorial axis.

If r be the component angular velocity about the axis OC of figure, then, since this angular velocity will not stir up the surrounding medium, the body being supposed to be a smooth solid of revolution, $c_6 r$ will be the component angular momentum about OC, c_6' being the moment of inertia of the body about OC; r will remain constant during the motion, the body being smooth and the medium frictionless.

Describe a sphere of unit radius with center O, and let OZ be the direction of the resultant linear momentum Z, OG of the resultant angular momentum G of the system, OC of the axis of figure. (In the figure the eye is supposed to be



at O, and looking at the concave side of the sphere—just as the eye sees the concave side of the celestial sphere.) The angular velocities p and r are estimated on the right-handed screw system (that is, an angular velocity r about OC is reckoned positive when on a right-handed

screw it would cause a transference from O to C).

If the center, O, of the body had been fixed, then OG, the axis of resultant angular momentum, would have been fixed, and the body would have behaved as if the equatorial and polar moments of inertia were c_4 and c_6; the axis OC would have described a right circular cone about OG as axis; and the motion might have been represented by rolling the right circular cone of axis OC and semi-vertical angle IOC, fixed in the body, on the right circular cone of axis OG and semi-vertical angle IOG, fixed in space; OI being the instantaneous axis of rotation, and therefore

$$\tan \mathrm{IOC} = \frac{c_6}{c_4} \tan \mathrm{GOC}.$$

But when the body moves steadily in the medium under no forces, O describes a uniform helix about a fixed straight line parallel to OZ, while OG, OI, and OC lie in a plane passing through OZ, which revolves with uniform angular velocity (μ suppose), while OC makes a constant angle (α suppose) with OZ, and OG makes a consant angle (θ suppose) with OC.

Then, if OA be the equatorial axis in the plane ZOC,

$c_1 u$=component momentum in the direction $\mathrm{OA} = \mathrm{Z} \cos \mathrm{ZOA} = -\mathrm{Z} \sin \alpha$,

$c_3 w$=component momentum in the direction $\mathrm{OC} = \mathrm{Z} \cos \mathrm{ZOC} = \mathrm{Z} \cos \mathrm{A}$;

and therefore, if OT be the direction of motion of O, the tangent to the helical path described by O,

$$\tan \mathrm{COT} = -\frac{u}{w} = \frac{c_3}{c_1} \tan \alpha.$$

In consequence of the direction of motion OT not being in the direction of the axis OC, the body will experience a couple about the axis OB, perpendicular to the plane AOC, of magnitude.

$$(c_3 - c_1) uw = \frac{c_3}{c_1} (c_1 - c_3) w^2 \tan \alpha.$$

Since the rate of change of angular momentum is equal to the impressed couple, therefore

$$\mathrm{G} \mu \sin (\alpha - \theta) = \frac{c_3}{c_1} (c_1 - c_3) w^2 \tan \alpha. \quad . \quad . \quad . \quad (1)$$

But

$\mathrm{G} \cos \theta$=component angular momentum about $\mathrm{OC} = c_6 r$,

$-\mathrm{G} \sin \theta$=component angular momentum about $\mathrm{OA} = c_4 p$;

and $p = -\mu \sin \alpha$,

since the velocity of C, considered as due to the angular velocity about OA is p, and due to the angular velocity about OZ is $\mu \sin \alpha$, and these are in opposite directions.

Therefore $\mathrm{G} \sin \theta = c_4 \mu \sin \alpha$,

$$\text{and } \tan \theta = \frac{c_4 \mu}{c_6 r} \sin \alpha.$$

But, from (1),

$$\mathrm{G} \mu \sin (\alpha - \theta) = c_6 r \mu \frac{\sin (\alpha - \theta)}{\cos \theta}$$

$$= c_6 r \mu (\sin \alpha - \cos \alpha \tan \theta)$$

$$= c_6 r \mu \sin \alpha - c_4 \mu^2 \sin \alpha \cos \alpha$$

$$= \frac{c_3}{c_1} (c_1 - c_3) w^2 \tan \alpha;$$

and dropping the factor $\sin \alpha$, which equaled to zero would imply perfect centering,

$$c_6 r \mu - c_4 \mu^2 \cos \alpha = \frac{c_3}{c_1} (c_1 - c_3) \frac{w^2}{\cos \alpha}.$$

$$\text{or} \quad c_4 \cos \alpha \mu^2 - c_6 r \mu + \frac{c_3}{c_1} (c_1 - c_3) \frac{w^2}{\cos \alpha} = 0; \quad . \quad . \quad . \quad . \quad . \quad (2)$$

a quadratic equation in μ.

Solving this quadratic,

$$\mu = \frac{c_6 r \pm \sqrt{\left\{ c_6^2 r^2 - 4 \frac{c_3}{c_1} (c_1 - c_3) c_4 w^2 \right\}}}{2 c_4 \cos \alpha},$$

and therefore the least admissible value of r, in order that the roots of this quadratic should not be imaginary, is given by

$$c_6^2 r^2 = 4 \frac{c_3}{c_1} (c_1 - c_3) c_4 w^2,$$

$$\text{or} \quad \frac{r^2}{w^2} = 4 \frac{c_3}{c_1} (c_1 - c_3) \frac{c_4}{c_6^2}.$$

If the shot had been fired from a gun of caliber $2a$, the rifling at the muzzle making one turn in n calibers, and β being the angle of rifling at the muzzle, then

$$\tan\beta=\frac{\pi}{n}=\frac{ar}{w}=2a\sqrt{\frac{c_3}{c_1}(c_1-c_3)\frac{c_4}{c_6^2}}. \quad . \quad . \quad . \quad (3)$$

If W = weight of shot,

W′ = weight of air displaced,

then

$$c_1=\mathrm{W}+\mathrm{W}'\alpha,$$
$$c_3=\mathrm{W}+\mathrm{W}'\gamma,$$
$$c_4=\mathrm{W}k_1^2+\mathrm{W}'k_1'^2\alpha',$$
$$c_6=\mathrm{W}k^2;$$

where k_1, k are the radii of gyration of the shot about OA and OC, and k'_1 of the air displaced (supposed rigid) about OA; α, γ, α' being certain quantities depending only upon the external shape of the body.

Where, as in practice, the fraction $\frac{\mathrm{W}'}{\mathrm{W}}$ is so small that its square may be neglected, we have

$$\tan^2\beta=\frac{\pi^2}{n^2}=4\frac{c_3}{c_1}(c_1-c_3)\frac{a^2c_4}{c_6^2}$$
$$=4\frac{\mathrm{W}+\mathrm{W}'\gamma}{\mathrm{W}+\mathrm{W}'\alpha}\cdot\mathrm{W}'(\alpha-\gamma)a^2\frac{\mathrm{W}k_1^2+\mathrm{W}'k_1'^2\alpha'}{\mathrm{W}^2k^4}$$
$$=4\frac{1+\frac{\mathrm{W}'}{\mathrm{W}}\gamma}{1+\frac{\mathrm{W}'}{\mathrm{W}}\alpha}\cdot\frac{\mathrm{W}'}{\mathrm{W}}(\alpha-\gamma)a^2\frac{k_1^2+\frac{\mathrm{W}'}{\mathrm{W}}k_1'^2\alpha'}{k^4}$$
$$=4\frac{\mathrm{W}'}{\mathrm{W}}(\alpha-\gamma)\frac{a^2k_1^2}{k^4} \quad . \quad . \quad . \quad . \quad (4)$$

+ higher powers of $\frac{\mathrm{W}'}{\mathrm{W}}$, which are neglected.

The only body for which α, γ, and α' have been, as yet, determined by mathematicians is the ellipsoid, the surrounding medium being supposed frictionless and incompressible; and for the particular case of the prolate spheroid of semi-axes a and c,

$$\alpha=\frac{\mathrm{A}}{\mathrm{A}+\mathrm{C}},\ \gamma=\frac{\mathrm{C}}{2\mathrm{A}},$$

and

$$\alpha'=\frac{\mathrm{A}-\mathrm{C}}{\frac{c^2-a^2}{c^2+a^2}(2\mathrm{A}+\mathrm{C})-\mathrm{A}+\mathrm{C}}\left(\frac{c^2-a^2}{c^2+a^2}\right)^2;$$

where

$$\mathrm{A}=\int_0^\infty\frac{d\lambda}{(a^2+\lambda)^2(c^2+\lambda)^{\frac{1}{2}}}$$
$$=\frac{c}{a^2(c^2-a^2)}-\frac{1}{2(c^2-a^2)^{\frac{3}{2}}}\log_\varepsilon\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}},$$
$$\mathrm{C}=\int_0^\infty\frac{d\lambda}{(a^2+\lambda)(c^2+\lambda)^{\frac{3}{2}}}$$
$$=\frac{1}{(c^2-a^2)^{\frac{3}{2}}}\log_\varepsilon\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}}-\frac{2}{c(c^2-a^2)}.\ *$$

and

$$2\mathrm{A}+c=\frac{2}{a^2c}. \quad (5)$$

From equations (4) and (5) Captain J. P. Cundill, R.A., has calculated a table of values of $\alpha-\gamma$ and the corresponding value of n for service projectiles, and the results obtained appear to agree very fairly with what is observed in practice. (See table, next page.)

It may be noticed from the formula that, on the hypothesis of the incompressibility of the medium, the value of n is independent of (1) the velocity, (2) the caliber, or length of bore; so that, for similar projectiles, one value of n would do for all guns in the service.

When, however, the velocity is high and the projectile is large, the compression of the air cannot be neglected, and the air behaves as if its density were increased; so that less rotation is required than that given by the formula.

For instance, the 80 and 100-ton guns are rifled at the muzzle with a twist of one turn in 50 calibers, while the formula would give one turn in 40 calibers as requisite for common shell three calibers long.

* "Quarterly Journal of Mathematics," Vol. XVI. "Mathematical Papers of the late George Green," edited by the Rev. N. M. Ferrers, p. 322.

Table calculated by Capt. J. P. Cundill, R.A., for Stability of Rotation of Projectiles.

Length of Projectile in cals.	Value of $\alpha-\gamma$.	Minimum twist at muzzle of gun requisite to give stability of rotation=1 turn in n calibers. Cast-iron common shell: Cavity=$\frac{8}{27}$ths vol. of shell. (s.g. of iron=7.207.)	Palliser shell: Cavity=$\frac{1}{8}$th vol. of shell (s.g.=8.000.)	Solid steel bullet. (s.g.=8.000.)	Solid lead and tin, similar comp'n to M.-H. bullets. (s. g.=10.9.)
		Value of n	Value of n.	Value of n.	Value of n.
2.0	.49418	63.87	71.08	72.21	84.29
2.1	.52032	59.84	66.59	67.66	78.98
2.2	.54431	56.31	62.67	63.67	74.32
2.3	.56643	53.19	59.19	60.14	70.20
2.4	.58679	50.41	56.10	57.00	66.53
2.5	.60561	47.91	53.32	54.17	63.24
2.6	.62315	45.65	50.81	51.62	60.26
2.7	.63938	43.61	48.53	49.30	57.55
2.8	.65454	41.74	46.45	47.19	55.09
2.9	.66868	40.02	44.54	45.25	52.72
3.0	.68192	38.45	42.79	43.47	50.74
3.1	.69434	36.99	41.16	41.82	48.82
3.2	.70598	35.64	39.66	40 30	47.04
3.3	.71693	34.39	38.27	38.84	45.38
3 4	.72724	33.22	36.97	37.56	43.84
3.5	.73697	32.13	35.75	36.33	42.40
3.6	.74615	31.11	34.62	35.17	41.05
3.7	.75483	30.15	33.55	34.09	39.79
3.8	.76303	29.25	32.55	33.07	38.61
3.9	.77082	28 40	31 61	32.11	37.48
4 0	.77820	27.60	30.72	31.21	36.43

The French Trans-Saharan Railway.—Some time ago the French Ministry of Public Works received a grant of about £2400 to assist in making a survey of a railway route across the Sahara to Timbuctoo, whence it is proposed ultimately to continue the line to the French settlements in Senegal. Three expeditions have left Algiers on this service, each detailed to a different portion of the route. Colonel Flatters, who commanded the principal expedition, has recently returned to Marseilles. He reports having reached the 24th parallel, about half way between Algiers and Timbuctoo, and 90 miles or so south of the large oasis of El Golea. The expedition found a reasonable amount of water on the way, and from the nature of the formation it is probable that ample supplies might be obtained by deep boring all along the line. In one part of their journey the explorers discovered a lake, surrounded by vegetation, and full of fish. From the great numbers of antelopes and other game, these fertile spots are probably not infrequent in this part of the Sahara. The celebrated traveler, Soleilet, is on his way from Senegambia to Timbuctoo to trace the proposed railway in that direction. The French Senate on Tuesday last passed a vote of credit of nine million francs for a farther preliminary survey; and, even although neither line should ever be constructed, these expeditions are sure to benefit geographical science, if they do not also open out practical caravan routes to the interior.

THE DEPHOSPHORIZATION OF IRON.

ON THE DEPHOSPHORIZATION OF IRON IN THE BESSEMER CONVERTER.

By R. PINK, Hörde, Westphalia.

From "Engineering."

At the opening of this communication I think it desirable to make some preliminary remarks, as I fear that otherwise the impression may prevail that, after a somewhat lengthened period of practice in dephosphorizing, even better results might have been obtained than those recorded here. The great object of this Institute is the promotion of progress in the industry whose name it bears. I trust you will allow that, if the progress here recorded has not been so rapid as some have expected, still, after making due allowance for the inevitable difficulties incident to grappling with a new system, a fair amount of success has been achieved.

It will be remembered that in April of last year, and again during the May meeting of this Institute, in presence of

many of its members, it was demonstrated that the problem of dephosphorizing iron in the Bessemer converter had, by the Thomas and Gilchrist system, been definitely solved at the works of Messrs. Bolckow, Vaughan & Co., under the direction of their talented manager. The Hörde Company, who had representatives at Middlesbrough and Eston during these experiments, at once determined also to test the process. It was then thought their plant was such as would make it comparatively easy for them to do this. They had a small plant of two 3-ton converters, and a larger one of three 8-ton vessels. There were at the time scarcely orders enough on hand to keep the larger plant going, and so the smaller one was left free for experimentation.

The revival of trade in the autumn of last year put quite a new phase on this condition of things. You are all aware that, in the heavy trades, when the harvest is ripe it must be gathered. This very revival of trade, welcome as it otherwise was and is, came at a conjuncture exceedingly unfavorable for the development of the new process, and in the midst of the experiments at Hörde attention had to be turned to the production of as large a quantity as both plants could possibly achieve. Owing to this circumstance, the new process had not the necessary time or space allotted to it for its sure and careful development, and, in reviewing what has been done, this fact must be taken into consideration.

The manufacture of good gray foundry pig at Hörde is always so costly that the margin of difference between it and Bessemer pig is too small to allow of this class of iron being used alone, and, considering the question entirely as one of dephosphorizing, it was determined to use poorer brands of white forge half-mine pig. In the use of this class of iron a claim may be laid to the progress before mentioned, and what has been done confirms both the possibility and probability of yet greater achievements in this direction. Without doubt we are making, from the very worst classes of pig iron, a most reliable and remarkably cheap steel.

In Hörde attention has not been paid to producing a better quality than that now in the market, but to making the same quality out of such irons as have just been mentioned. As good reliable rails are made by the Bessemer process with .08 per cent. of phosphorus in them, rails are made by the new process with .07 per cent. or .06 per cent., these being considered equal to all the requirements of railway material. For axles, tyres, plates, and wire billets the phosphorus is reduced to a much lower figure than this.

On the 22nd of last September, Hörde got, after great delay in looking for the best class of kiln to burn the bricks and dolomite in, one 3-ton converter at work, and at the same date rolled direct from the ingot the first rail manufactured under the Thomas patent in Germany. This rail stood exceedingly well under the tup, in spite of the phosphorus showing .12 per cent., but by the third charge the phosphorus was reduced to .06 per cent., and from this period, with but one exception, no difficulty has been found in keeping the phosphorus within the limits of .08 per cent. to .04 per cent.

At first, copying the example of Middlesbrough, iron was used containing as much as 1.5 per cent. of silicon, and it was determined to reduce this body by at least one-half. That it is possible to do so without detriment to the charge was soon apparent, as white forge pig containing but .73 per cent. of silicon was melted with 20 per cent. of steel scrap in the cupola without the metal boiling over in the converter in a sensibly higher degree than usual, while it allowed the ingots to be cast ascensionally. Guided by these results, silicon has always been kept low, and, as a consequence, white forge pig can be used instead of the much more costly foundry Nos. 1 and 2.

In order to increase the fluidity of this class of metal, and if possible to add an increment of heat, it was resolved to make a forge pig containing at least 1 per cent. of manganese, and, although the expectations entertained of thereby fluxing the basic additions at an earlier period in the charge have not been fully realized, this body doubtless does act as desired in the first two cases, and assists also to remove the sulphur that may be contained in the metallic bath. Man-

ganese may be termed the key to the use of cinder pig, where it can be cheaply and in sufficient quantities introduced into the iron in the blast furnace, or later in the Bessemer converter.

With the object of getting still greater heat on the metal, iron with larger percentages of phosphorus has been used, and the great value of this is clearly demonstrated; for when 2 per cent. of this metalloid is contained in the charge to be converted, groups of eight 10-inch ingots can be cast ascensionally with perfect ease, the steel being so quiet in the moulds as to allow of its being stoppered with light iron stoppers instead of the troublesome and dirty sand stopping.

Of course, the quantity of basic additions has to be increased, but not in so great a ratio as to be excessively expensive, or to cause trouble in the converter. Never less than 15 per cent. of good burned lime is used, be the amount of phosphorus what it may; and when working irons with upwards of 2 per cent. of phosphorus, 20 per cent. of lime is found quite sufficient. In the first case the lime is badly fluxed, and in the second the slag is very fluid. The fluxing of the lime has been attributed by many to the excessive waste of iron during the overblow, the oxides of which were supposed to reduce the slag to this state of fluidity, but on looking at the subjoined analyses it will be found that the waste of iron is not excessive.

To produce sound homogeneous ingots a good percentage of phosphorus—say between 1 and 2 per cent., or even in excess of this latter figure—appears to be indispensable, and irons containing so low a percentage as .5 do not appear suitable, unless this body is introduced in the charge by one or other of the known means, the best of which appears to be the use of ferro-phosphorus. That phosphorus can and does replace silicon, as a source of heat in the Bessemer converter, when working on the system Thomas-Gilchrist is no longer to be disputed.

The method of carrying out the process at Hörde is as follows: After heating up the converter, and without tipping out the coke used in so doing, the lime mixed with a little small coal is added, and, after blowing through for a few minutes, the metal is run in. In the three-ton converters the time occupied in blowing a charge of from 3 tons 10 cwt. to 4 tons, up to the vanishing point of the carbon lines of the spectrum, varies from 9 to 13 minutes, and the after-blow from 115 to 200 seconds. A test piece is taken shortly before the charge is considered as finished; this, when forged, is cooled in water and then broken, after which the blowing is continued as may be considered necessary. A second test piece is now rarely taken, as the first is so timed that a further half or three-quarter turn-up of the converter suffices to finish the charge. The slag is then run off and the spiegeleisen added. This running off of the slag prevents in a great measure the reduction of phosphorus out of the same, by means of the fluid addition.

Good sound burnt lime broken up to about the size of hens' eggs, and used as fresh as possible after burning, has been found to be the best basic addition; and could this be introduced cheaply and expeditiously in a white or red-hot state into the converters, it would prove of great advantage. The lining of the converters will be better protected during the oxidation of the silicon and a fluid slag earlier formed by this means.

The details of three charges are given below, and their analyses show clearly the chemical changes that take place during the blowing of the charge.

Charge No. 67, composed of

2400 lbs.	of	foundry No. 3
3000	"	white forge
1000	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.
6820 lbs.		total raw material.

Weight of steel produced, 6074 lbs.

Charge No. 68, composed of

24(0 lbs.	of	foundry No. 3
3000	"	white forge
1200	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.

7020 lbs. of raw material and 6250 of ingots.

Charge 69, composed of

1800 lbs.	of	foundry No. 3
3600	"	white forge
1200	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.

7020 lbs. of raw material and 6302 lbs. of ingots.

The total iron used in these three charges amounted to ....20,860 lbs.
And steel produced ....18,626 "

Giving a loss of .... 2235 "
or 10.17 per cent.

In the testing machine the following results were obtained:

Steel from charge No. 67 showed a tensile strength of 50.1 kilogs. per square millimeter of section (say 72,000 lbs. per square inch), with an extension of 20.6 per cent. and a contraction of area at point of breakage of 44.8 per cent.

Steel from charge No. 68 showed a tensile strength of 53.5 kilogs. per square millimeter of section, with an extension of 22 per cent., and contraction of area

ANALYSES OF CHARGE No. 67.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola	1.04	2.58	0.22	1.35	1.08
After blowing 11.75 minutes on fall of carbon lines	0.82	0.08	0.19	0.39	0.09
At overblow of 100 seconds	0 08	0.06	0.15	0.39	0.007
And further overblow of 15 seconds	0.045	0.04	0.14	0.37	0.005
After addition of spiegeleisen	0.06	0.28	0.067	0.46	0.002

ANALYSES OF CHARGE No. 68.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola	0.96	2.82	0.16	1.04	0.45
After 14 minutes blowing, and at fall of carbon lines	0.70	0.09	0.16	0.40	0.02
At overblow of 110 seconds	0.09	0.085	0.15	0.33	0.003
At further overblow of 15 seconds	0.05	0.08	0.09	0.29	0.000
After adding the spiegeleisen	0.06	0.26	0.055	0.31	0.000

ANALYSES OF CHARGE No. 69.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola	1.04	2.73	0.27	1.39	0.72
After 12 minutes blowing, and at fall of carbon lines	0.74	0.08	0.18	0.45	0.14
At 120 seconds afterblow	0.06	0.07	0.12	0.19	0.004
After addition of spiegeleisen	0.06	0.24	0.063	0 40	0.000

The slags contained 1.8 per cent. of metallic iron, and were composed as follows:

	Charge 67.	Charge 68.	Charge 69.
	per cent.	per cent.	per cent.
Silica	9.50	13.81	11.10
Phosphoric acid	9.76	7 38	12.43
Magnetic oxide ($Fe_3 O_4$)	9.28	6.92	10.25
Peroxide of iron	..	1 41	
Oxide of manganese ($Mn_3 O_4$)	6.16	6.20	4.40
Lime	59.35	57.85	50.21
Magnesia	5.01	6.93	9.84
Sulphate of lime	0.87	0.22	1.15
Alumina	trace	trace	trace

at point of breakage of 47 per cent.

Steel from charge No. 69 gave a tensile strength of 54.3 kilogs. per square millimeter of section, with an extension of 19 per cent., and contraction of area at point of breakage of 42 per cent.

All the test pieces had a length of 150 mm., and a diameter of 15 mm.

These analyses and details must be apologized for to those members who are already acquainted with them. They are of an early date, but the Hörde Company do not feel justified in publishing later ones, pending the investigations of Geheimrath, Dr. Wedding, and Professor Finkener, as well as those of Dr. Müller and Dr. Fischer, the latter of whom has taken very elaborate samples of the gases evolved during the process and at the time of casting. These results will be public property at no very distant date, and will doubtless clear up certain hitherto conflicting theoretical views.

A repetition of the views propounded on the *rationale* of the process by the best metallurgists of the day would here be useless, as a large literature on this subject already exists, and the great interest excited is vouched for by the investigations not only of the gentlemen already mentioned, but of MM. Tünner, Grüner, Snelus, Pourcel, Jourdan, Riley, Ehrenwerth, Stead, Gautier, Massenez, &c.

The results of the three charges, Nos. 67, 68, and 69, show that without great loss of iron, silicon can be kept low, and by having manganese in the bath a great deal of the sulphur is also removed. These facts point to the wished-for end, namely, the use of a cheap cinder pig. The charges given only show a loss of 10.7 per cent., but the average loss at present comes up to about 17 per cent. When pit scrap, skulls, &c., are weighed in, this amount is reduced to something like 15 per cent.

A point of some importance in connection with this process is the blocking up of the converter with slag, and in cases where proper provision against this has not been or cannot be made, it proves the source of much delay. To provide against such a defect, many methods of fluxing the basic additions at an early period of the process have been tried with but negative success. At Hörde, however, a system has been used that is very promising; and when a proper isolating medium for separating the acid from the base is used, there is no doubt blocking up will be greatly reduced, if not entirely got rid of. The system referred to is the building in of good fire clay bricks on the points where the slag adheres, principally on the back of the throat and along the slag line of the converter when in its teeming position. At first, only 12 inches down the throat were so lined, but behind this the block-up was as great as usual. This zone was then deepened to 5 ft. in a converter of 16 ft., and the nose kept perfectly clean where the fire bricks were built in; still the slag blocked up directly below this zone. This is, however, of small importance, and, indeed, tends to keep the iron from boiling over, while its position in no way interferes with the regular working of the converter.

The blocking up of the converter appears not to be thoroughly understood; for whereas the Rhenish Steel Company have no cause of complaint with their 6-ton converters, and Hörde no difficulty with the 3-ton ones, the 8-ton vessel of the latter firm causes a good deal of trouble. No difficulty has been found in eliminating the phosphorus, even when such large patches of fire brick have been used as here are referred to.

The small converters can be much more rapidly manipulated than the larger ones, and the delay in taking the tests is not half so great. Delay is the cause of more blocking up than anything else. To avoid this, there appears as the very best remedy, exceedingly rapid manipulation of the whole plant and the reduction of the necessity of taking many, or any tests during the charge. When working with a perfectly known quantity of phosphorus and silicon, the former can be reduced to .07 or 0.08 without even once testing. Again, when the bottoms do not stand, the blocking up is very bad. This is no doubt caused by the insufficient fluxing of the dolomite loosed from the bottom. The slag, being then thicker, adheres more easily. In all cases, the heat of the charges has been greater and the blocking up less when using the highest obtainable blast pressure.

Great speed in working, together with

large ladles, that allow of rapid teeming, combined with a sufficiency of phosphorus and manganese, as also good bottoms, with a minimum duration of ten charges, and the use of fire brick zones at the points most liable to incrustation, appear to be the solution of this inconvenience. Bottoms cause trouble principally on account of the irregularity, giving at one time sixteen charges, and then, again, only four or five. The undoubted cause of this is the insufficient calcination of the dolomite, which, when exposed to the influence of the atmosphere after being ground, or even when grinding, rapidly absorbs moisture. It must be admitted that, if the causes of bad bottoms are as above stated, with more experience and care in preparing them they ought all to go up to the highest figure here given.

The average life of bottoms either rammed round pins or clay tuyeres reaches about nine charges, and with bricked ones better results have only been obtained occasionally.

Converter linings last, including the necessary patching, from 90 to 130 charges. Patching consumes about 50 per cent. of the amount of bricks required when first lining up, so that a 3-ton converter requires for, say, 120 charges, or a total production of 460 tons, as near as possible 4500 basic bricks.

The irons now used at Hörde are their own rejected foundry No. 3, foundry scrap, a half-mine forge pig, the white forge pig of Messrs. De Wendel, Messrs. Metz, of Luxemburg, and that of the Ilsede Company in the province of Hanover. This latter contains as much as 3 per cent. of phosphorus and about 2.5 per cent. of manganese.

The 3-ton plant produces about 40 tons daily, very nearly the same as when working the same converters acid lined. The shop is so cramped for room that rapid working is an impossibility.

In this department, tyres, axles, plates, and material for wire are solely manufactured. Upwards of 4000 tyres have already been turned out, and many hundreds of axles. Everything is cast ascensionally, the tyre ingots in groups of four, the axles in groups of three double ingots, whilst for wire, 8-inch parallel ingots in groups of four are cast. These latter weigh about 600 lbs., and are rolled down to $1\frac{1}{4}$-inch billets in one heat on a 12-inch train.

The 8-ton plant has, for want of sufficient basic material, and during the alterations now making, only one of the three converters working on the system. This has to take its turn with the others, and from causes mentioned at the commencement of this communication, the production has not been so regular as that of its small neighbor. Here only rail ingots are cast, in groups of eight, of 10-inch square. These are then rolled direct in one heat, without previous forging or cogging.

Doubts have been expressed as to the capability of producing hard steel by this process. Little experience has been gained in Hörde in this direction, as nearly all orders are for comparatively soft material. The axle orders are specified as not under 50 kilogs. of tensile strength per square millimeter of section, and a contraction at the point of breakage of not less than 35 per cent. For tyres, the lowest tensile limit is 45 kilogs., and the least allowable contraction 35 per cent. However, the sum of the tensile strength plus the contraction must reach 90.

Such conditions can be fully met, and many test pieces show up to 63 kilogs. with a contraction of 39 per cent. This being the general quality desired, no efforts have been made at producing harder steel.

In the softer qualities, for plates, wire, &c., it is at times astonishing what results are obtained. With 37 to 40 kilogs. of actual breaking weight, as much as 70 per cent., and in some cases even 75 per cent., of contraction has been reached. At the same time, this ingot iron can take very high heats, forging and rolling without a flaw. The production of this especial quality is so simple, the cheapness of the raw material, the certainty in working, its softness, and its ductility, all point to its driving at no very distant date puddled iron plates out of the market. For wire even of smallest gauges it has been declared better than that drawn from billets puddled from charcoal pig. Some small specimens are on the table for your inspection, and as most of the members will probably visit Düsseldorf during the autumn meeting, the exhibi-

tion there will show you what can be achieved in this respect.

An interesting and practical proof of the quality of this steel has been given during the last few days. The fire-tube of a Cornwall boiler, at one of the mines in the neighborhood of Dortmund, had to be removed on account of two of the plates bulging in. The water with which this boiler was fed contained such large quantities of common salt that an incrustation of several inches was formed in a very short space of time. Under these circumstances the plates got red-hot and buckled in. They show no flaw, although the indentations are in some cases 4 feet long, from 6 in. to 18 in. wide, and 7 in. or 8 in. deep. These plates were manufactured at Hörde under the system of Messrs. Thomas and Gilchrist in February of this year.

The character of plant that the Hörde Company possess is ill-suited to the requirements of this process, which accounts for its slow development, and Hörde has had the disadvantage of being the experimental bureau for Germany. In order to get the full benefit that the process undoubtedly brings, special plant should be designed for it. Spacious shops, with good facilities for clearing the pits of ingots and slag boxes, are very desirable; possibly also the converters should be built up in sections, and, above all, plenty of blast and great speed in working. When a charge of 8 tons of white forge iron, containing up to two per cent. of phosphorus, is converted, including the afterblow, in eight or nine minutes, the metal will be at least as hot as that when grey silicious pig is used by the old method. In proof of this, a charge of white phosphoric pig was blown in the presence of Geheimrath, Dr. Wedding, and Professor Finkener, and for the purpose of getting a correct diagram the charge was turned down no less than eight times to take the necesssary tests. The actual time of blowing was under nine minutes, and the steel ran ascensionally as well as could be wished for, without the least skull.

At the Rhenish Steel Works in Ruhrort, the process is worked even more successfully than at Hörde, and the following German firms have arranged for working, or are working, under this system; Messrs. De Wendel, Messrs. De Dietrich, Gienauth Brothers, Stumm Brothers, the Lothringen Iron Works at Ars on the Moselle, the Burbach Iron Works, the Rothe Erde by Aachen, the Bochum Company, the Königen Marien Works in Saxony, and others.

I have purposely avoided the theoretical side of the question, leaving this to be dealt with by those who have devoted so much valuable time to it, and who have already given, and in the immediate future will doubtless again give, you a library of information on the subject.

THE TAY BRIDGE.

From "The Architect."

The reports of the Board of Inquiry into the "Circumstances attending the fall of a portion of the Tay Bridge on December 28, 1879," have been published, Colonel Yolland and Mr. Barlow being the joint authors of one, and Mr. Rothery of the second.

The report of Colonel Yolland and Mr. Barlow begins with a history of the Tay Bridge and a description of the mode of construction. In referring to the quality of the workmanship they say—

In regard to imperfection of workmanship and fitting, we observe, in the first place, that, as the substitution of iron in place of brick piers in this part of the work arose after the contract was let, there are no clauses in the specification describing the class of workmanship to be employed in them. The stipulation in the general specification, which requires all the holes in the flanges of the columns to be drilled, was not carried out in this part of the work as regards the holes in the flanges of the 18-inch columns. The holes in the lugs on the columns were all cast and left conical, instead of being drilled, thus allowing the pins to be bent and to have unequal bearings. Some of the sling plates which were made or altered at the works were roughly formed. Imperfection of

workmanship was also found in the bolt-holes of the struts, and as the struts did not abut against the columns, as in our opinion they ought to have done, their action in these cases depended on the friction or resistance to movement made by bolting the channel irons tightly together and bearing hard against the lugs. The columns after the accident were found in some instances to be of unequal thickness, and to have other defects of casting, and it was probably due to the sluggish character of the metal and the manner in which the columns were cast that the castings of the lugs did not always turn out sound, as out of fourteen tie bars attached to lugs tested in London, four showed unsoundness to a greater or less extent at the lugs. It is stated in evidence that, in some cases where lugs had turned out imperfect in casting, other lugs or portions of lugs were added by a process termed "burning on." This is admitted to have been done; but it is denied that any columns so treated were used in the permanent structure, and, although a large number of broken lugs are visible in the ruins of the fallen bridge, none were found during Mr. Law's examination, nor have been otherwise brought to our notice, which appear to have been subjected to this most objectionable and dangerous process.

The subject of wind pressure is afterwards considered, and the two Commissioners are of opinion that Sir Thomas Bouch, the engineer of the bridge, was not justified in supposing that Sir John Hawkshaw and other engineers had affirmed that no special provision for wind pressure was requisite:

We think he must have misunderstood the nature of that report, for as it is pointed out that the pressures in gusts of wind amounted to 40 lbs. or 50 lbs., it was obviously necessary to provide for the pressures of these gusts in each of the spans of the Tay Bridge; and although the limited area of these gusts is described as not being at all comparable to that of the Forth Bridge of 1,600 feet span, yet they might in effect be equal to the whole area in the Tay bridge spans of 245 feet, and their operation might take place upon any of the spans. It must not be understood, however, that we express an opinion as to the sufficiency of a provision for only 10 lbs. of wind pressure in a large span of 1,600 feet. It may represent an amount of force which, as applied to the whole surface, would rarely be exceeded, but it occurs to us as possible that two or more gusts might act simultaneously on so large a span, or there might be a wind gust of unusual width. . . . In the great majority of railway structures, namely, those made in brickwork and masonry, as well as iron bridges of moderate height and span, special provision is not required for wind pressure, because the weight and lateral strength imparted to such structures in providing for the strains due to dead weight and load is more than sufficient to meet any lateral wind pressures which can arise. Also, in girders up to considerable spans, the lateral stiffness given to them to resist the tendency to oscillation produced by moving loads at high speeds is generally sufficient to meet the requirements of wind pressures; and the evidence of Sir Thomas Bouch implies that, having provided amply for dead weight and moving loads in the Tay Bridge, he did not consider it necessary to make special provision against wind pressure.

The gradual deterioration of the bridge, and the causes to which Colonel Yolland and Mr. Barlow attribute the accident, are thus described:

The first indication of weakness in the bridge itself was the loosening of a number of the ties of the cross bracing, a fact observed by the inspector, Henry Noble, in October 1878. He did not communicate this fact to Sir T. Bouch, but procured iron and packed the gibs and cotters, using for this purpose more than 100 iron packings about three-eighths of an inch thick in different parts of the bridge. All the evidence relative to the condition of the ties states that they were, to all appearance, in proper order at the date of the inspection by General Hutchinson, on February 25, 26, and 27, 1878. The loosening which subsequently ensued must have resulted from lateral action, and was most probably due, as Sir T. Bouch suggested, to strains on the cross-bracing produced by storms of wind. Sir Thomas Bouch considers that the effect produced arose from the bending of the pins in the holes, which had been left

conical in casting the lugs, and it was, we think, one of the causes; but the small bearing surfaces between the gibs and cotters and the tie bars, only about .375 of a square inch, would tend to increase this effect, and it might have been further increased by displacement or movement at the ends of those struts where the fitting was imperfect.

In October or November, 1879, three of the columns were ascertained by Mr. Noble to be cracked with vertical cracks, two of them being in the Northern part of the bridge still standing, and one in pier No. 38 under the high girders. The inspector (Noble) bound these columns round with wrought iron bands, and communicated this fact to Sir Thomas Bouch, who came to the work, and, in reference to other defects pointed out by the inspector, decided to have extra bracings made for the curved part of the bridge north of the large girders. It has been already mentioned that the columns of the whole bridge were filled after their erection with Portland cement concrete, put in from the top, and concrete of this material, unless carefully managed, is liable to swell in setting. From this circumstance, and from the unequal contraction of cast iron and concrete by cold, internal strains might have arisen sufficient to produce such cracks. Cracks of a like character have occurred in other viaducts, and when the fracture is vertical it is capable of remedy to a considerable extent by hooping with wrought iron bands. In this state of the columns and ties, the storm of December 28, 1879, occurred, which would necessarily produce great tension on the ties, varying as the heavy gusts bore upon different parts of the bridge; and when under these strains, the train came on to the viaduct, bringing a larger surface of wind pressure to bear as well as increased weight on the piers, and accompanied by the jarring action due to its motion along the rails, the final catastrophe occurred.

The distance at which the girders were found from the piers, and the position of the wreckage on the piers, is such as would result from a fracture and separation occurring somewhere in the piers above the base of the columns, and such a fracture might have arisen from two causes—firstly, by the yielding of the cross-bracing, and the consequent distortion of the form of the piers, which would throw unequal strains on the flanges and connecting bolts; or, secondly, fracture might have occurred in one of the outer leeward columns, from causes similar to those which produced the fractures found in other columns shortly before the accident.

Sir T. Bouch states it to be his opinion that the accident was occasioned by the overturning of the second-class carriage and the van behind it by the force of the wind, that they were canted over against the girder, and that the force of the blow given by these vehicles at the speed at which they were traveling was sufficient to destroy portions of the girders, and so occasioned the fall. But in this opinion we do not concur, and do not consider that it is supported by the evidence of the engineers who were called on the part of the railway company, Sir T. Bouch, and the contractors. Dr. Pole, Mr. Stewart, and Mr. Baker, all of whom were called on behalf of Sir T. Bouch, although they suggest the possibility of some shock acting in addition to the wind pressure, all concur in attributing the first failure to the lugs of the cross bracing. Mr. Cochrane believes that if the columns had been strongly braced, strongly fitted, and strongly held down by holding-down bolts, the pier would have been standing now, and adds, "It is a question of cross-bracing, of course." In our opinion the weight of evidence points out the cross-bracing and its fastening by lugs as the first part to yield.

Such being the nature of the case brought under our consideration in this inquiry, we have to state as our opinion:

1. That there is nothing to indicate any movement or settlement as having occurred in the foundations of the piers which fell.

2. That the wrought iron employed was of fair strength, though not of high quality as regards toughness.

3. That the cast iron was also fairly good in strength, but sluggish when melted, and presented difficulty in obtaining sound castings.

4. That the girders which have fallen were of sufficient strength, and had been carefully studied in proportioning the several parts to the duty they had to

perform. In these girders some imperfections of workmanship were found, but they were not of a character which contributed to the accident, and the fractures found in these girders were, we think, all caused by the fall from the tops of the piers.

5. That the iron piers used in place of the brick piers, originally contemplated, were strong enough for supporting the vertical weight, but were not of a sufficiently substantial character to sustain, at so great a height, girders of such magnitude as those which fell. That the cross bracing and its fastenings were too weak to resist the lateral action of heavy gales of wind.

6. That, although a large staff of assistants and inspectors was employed, we consider that a sufficiently strict supervision was not exercised during the construction of that part of the work made at the Wormit Foundry. We think that the great inequality of thickness in some of the columns, the conical holes cast in the lugs, and several imperfections of workmanship which have been ascertained by this inquiry, ought to have been prevented.

7. That the arrangements for the supervision of the bridge after its completion were not satisfactory, inasmuch as it was intrusted solely to Henry Noble, who, though an intelligent man, and very competent in the class of work to which he had been accustomed, possessed no experience in structures of iron work, nor does it appear that he received any definite instruction to report as to the state of the iron work of the bridge.

8. That Henry Noble, having become aware that many of the ties of the cross-bracing were loosened in October, 1878, ought at once to have informed Sir T. Bouch of this circumstance. Had he done so, there would have been ample time to have put in stronger ties and fastenings before the occurrence of the storm which overthrew the bridge.

9. That the ties of the cross-bracing had been tightened up and brought to their bearing before the date of the inspection by General Hutchinson, and the fact that many of them became loose so soon afterwards, was an evidence of weakness in this part of the structure, and of a departure from the vertical of the columns where it occurred; and we think that the loosening of the ties to an extent sufficient to permit the insertion of pieces of iron three-eighths of an inch thick indicated a considerable change of form of the pier, and rendered it doubtful if the piers could have recovered their form when the wind action ceased. The employment of packing pieces, under such circumstances, might have had the effect of fixing the parts of the structure where they were applied in their distorted form.

10. That, notwithstanding the recommendation of General Hutchinson, that the speed of the trains on the bridge should be restricted to 25 miles per hour, the railway company did not enforce that recommendation, and much higher speeds were frequently run on portions of the bridge.

11. That the fall of the bridge was occasioned by the insufficiency of the cross-bracings and its fastenings to sustain the force of the gale on the night of December 28, 1879, and that the bridge had been previously strained by other gales.

12. That, although the general bearing of the evidence indicates the cross-bracing as being the first part to yield, yet it is possible that the fall of the bridge may have been occasioned by a fracture or partial fracture in one of the outward leeward columns, produced by causes analogous to those which fractured other columns shortly before the accident; for if a fracture or partial fracture of a dangerous character occurred in one of these columns, the extra strain brought on by the force of the gale, accompanied by the weight and tremor of the train, might have led to its final rupture.

13. That the first or southern set of continuous girders, covering five spans, was the first that fell after the engine and part of the train had passed over the fourth pier, and that the two consecutive sets of continuous girders, each covering four spans, were in succession pulled off the piers on which their northern ends rested, by the action of the first set of continuous girders falling over, and probably breaking some of the supporting columns.

14. That the extent of the work which fell was attributable to the employment

of long continuous girders supported by piers built up of a series of cast-iron columns of the dimensions used.

In conclusion, we have to state that there is no requirement issued by the Board of Trade respecting wind pressure, and there does not appear to be any understood rule in the engineering profession regarding wind pressure in railway structures; and we therefore recommend that the Board of Trade should take such steps as may be necessary for the establishment of rules for that purpose.

We also recommend, before any steps are taken for the reconstruction of the Tay Bridge, that a careful examination should be made of those parts of the structure left standing, especially as regards the piers, with a view to insuring such alterations and amendments as may be necessary to give to these portions of the work complete stability.

Mr. Rothery says that he agrees with his colleagues in thinking that there is no evidence to show that there has been any movement or settlement in the foundations of the piers; that the wrought iron was of fair quality; that the cast iron was also fairly good, though sluggish in melting; that the girders were fairly proportioned to the work they had to do; that the iron columns, though insufficient to support the vertical weight of the girders and trains, were, owing to the weakness of the cross-bracing and its fastening, unfit to resist the lateral pressure of the wind; that the imperfections in the work turned out at the Wormit Foundry were due in great part to a want of proper supervision; that the supervision of the bridge after its completion was unsatisfactory; that if by the loosening of the bars the columns got out of shape, the introduction of packing pieces between the gibs and cotters would not bring them back to their position; that trains were frequently run through the high girders at much higher speed than at the rate of 25 miles an hour; that the fall of the bridge was probably due to the giving way of the cross-bracing and its fastening; the imperfection in the columns might also have contributed to the same result. But he differs from them in the interpretation of the instructions under which the Court of Inquiry was held.

I apprehend (says Mr. Rothery) that if we think the blame attaches to any one for this casualty, it is our duty to say so, and to say to whom it applies. I do not understand my colleagues to differ from me in thinking that the blame for this casualty rests with Sir Thomas Bouch, but they consider that it is not for us to say so. Lastly, my colleagues, in their report, call attention to the fact "that there is no requirement issued by the Board of Trade respecting wind pressure, and that there does not appear to be any understood rule in the engineering profession regarding wind pressure on railway structures," and they therefore "recommend that the Board of Trade should take such steps as may be necessary for the establishment of rules for that purpose." I cannot, however, join in that recommendation, for it appears to me that if there is no understood rule in the engineering profession, regarding wind pressure on railway structures, it is for the engineering profession, and not for the Board of Trade, to make them. I will add, that if I rightly understood my colleagues at our last interview, they concurred in the conclusions to which I had come, that there might be a maximum wind pressure of from 40 lbs. to 50 lbs. per square foot, and this too, not only over a few feet, but over the whole extent of a span of one of the high girders, and I gather as much from their report. And, if so seeing that it is the practice in France to allow 55 lbs. per square foot for wind pressure, and in the United States 50 lbs., there seems to be no reason why a similar allowance should not be made in this country.

After an examination of the defects in the design as well as in the construction of the bridge, Mr. Rothery reports :

The conclusion, then, to which I have come is, that this bridge was badly designed, badly constructed, and badly maintained, and that its downfall was due to inherent defects in the structure, which must sooner or later have brought it down. For these defects in the design, the construction, and the maintenance, Sir Thomas Bouch is, in my opinion, mainly to blame. For the faults of design he is entirely responsible. For those of construction he is principally to blame in not having exer-

cised that supervision over the work which would have enabled him to detect and apply a remedy to them. And for the faults of maintenance he is also principally, if not entirely, to blame in having neglected to maintain such an inspection over the structure as its character imperatively demanded. It is said that Sir Thomas Bouch must be judged by the state of our knowledge of wind pressures when he designed and built the bridge. Be it so; yet he knew or might have known that at that time the engineers in France made an allowance of 55 lbs. per square foot for wind pressure, and in the United States an allowance of 50 lbs. And although there seems to have been no agreement among English engineers as to the allowance proper to be made, Mr. Brunlees told us that he allowed 30 lbs., and even Mr. Baker allowed 28 lbs. Sir Thomas Bouch was building a bridge on somewhat new principles, and in a position where it would be peculiarly exposed to the action of westerly and south-westerly gales; and not only does he make no allowance for wind pressure, but actually builds the bridge weaker and lighter and with wider spans than in his previous works. To have built and designed a bridge which, if properly constructed in all respects, would only have borne a lateral pressure of from 60 lbs. to 70 lbs. per square foot when a pressure of 40 lbs. or 50 lbs. of wind was quite possible, was a grave error of judgment. Whether, too, the calculation of its stability, or the maximum pressure of the wind be or be not erroneous, matters very little; the bridge fell in a gale of wind which, though violent, was not one which could not and ought not to have been provided against. It fell solely by the action of the wind, either when the margin of safety was too low or the defects too great. In neither way can Sir Thomas Bouch escape his responsibility.

I think, also, that Messrs. Hopkins, Gilkes & Co. are not free from blame for having allowed such grave irregularities to go on at the Wormit Foundry. Had competent persons been appointed to superintend the work there, instead of its being left almost wholly in the hands of the foreman moulder, there can be little doubt that the columns would not have been sent out to the bridge with the serious defects which have been pointed out. They would also have taken care to see that the bolt-holes in the lugs and flanges of the 18-inch columns were cast truly cylindrical, or, if that could not be done, they would have called the attention of the engineer or his assistants to the fact; but that does not appear to have been done. The great object seems to have been to get through the work with as little delay as possible, without seeing whether it was properly and carefully executed or not.

COMPRESSED AIR LOCOMOTIVES.

From "The Engineer."

The bringing out of a limited company, with a large nominal capital, to work a locomotive engine driven by compressed air, is sure to arouse public attention to the merits and demerits of this form of motor. It cannot be denied that hitherto the demerits have been rather the more prominent of the two. As far as practical results go, great efforts were made to achieve the success of the Mekarski air engine at Paris, but the attempt, we believe, has been entirely abandoned. In Glasgow, Mr. Scott Moncrieff has built what appeared to be a promising engine of the same type but it lingers, we fear, in the inglorious inactivity of the shed. Even for those purposes, such as tunneling, in which compressed air has come largely into practical use, engineers agree that its efficiency is lamentably low, and that it is only its extreme convenience in other ways which makes its employment a necessity. It may be interesting, therefore, to our readers, to put before them the precise conditions of the problem which Col. Beaumont has attacked, and in the light of such facts as have been

placed before the public, to consider how far he may be credited with having solved it.

The great advantages that would follow from some cheap and convenient method of storing up power, to be given out at any subsequent time as needed, are so obvious that they do not need to be dwelt upon. At first sight it would seem that the compression of air was specially fitted to form a method of this kind. Air is readily and simply compressed to any required extent; it has practically no weight and no dangerous properties of any kind; a very large quantity of power can thus be stored up in a vessel of comparatively small size and weight, and when this power is required for use, the emission of the air is not only attended with no inconveniences, but in some circumstances, *e. g.*, underground, is absolutely beneficial. When, however, it is attempted to carry this promising device into practice, it is found that two great obstacles bar the way; firstly, the difficulty in preventing leakage; and, secondly, the great loss of useful effect which takes place both during the compression and during the expansion. The first difficulty, that of leakage, is entirely practical, and one that no engineer will undervalue; but it is obvious that it must be entirely overcome if the storing up of power is to continue for any considerable length of time. The second difficulty, the loss of useful effect, is of a more theoretical and recondite character, and by many engineers it is either ignored altogether, or regarded as something abstruse and mysterious. We believe, however, it can be made perfectly plain to anybody acquainted with the first principles of mechanical science, and we will therefore devote a few words to the subject.

With air, as with any other permanent gas, there are three properties, which may be said to exhaust all that, from a physical point of view, we can want to know about it, namely, its pressure, its volume, and its temperature. When, for instance, we know that a certain quantity of air occupies a reservoir whose content is 300 cubic feet, that a pressure gauge attached to that reservoir stands at 1000 lbs. to the square inch, and that a thermometer also attached registers 60 deg. Fah.—these are somewhere about the normal conditions of Col. Beaumont's engine, now running experimentally at Woolwich—then there is only one other question which we can need to ask concerning it; and that question is, "How great is your certain quantity?" This is answered by stating the volume of the same air under standard circumstances, *i. e.*, under ordinary atmospheric pressure and temperature. Thus to investigate any problem concerning air we must know four quantities—the pressure, the temperature, the volume, and the initial volume, or the volume under standard conditions. But, on examining the matter further, theory shows that these four quantities are so dependent on each other, that if any three be given the fourth can always be calculated from them; hence, if we take any given initial volume of air and follow it through changes of any kind, we find that its pressure always depends on its temperature and its volume, its volume on its temperature and its pressure, and lastly, its temperature on its pressure and its volume; so that any change that takes place in any one of these quantities will be followed immediately by a change, greater or smaller, in one at least of the two. To put the matter in another form, a given quantity of gas, whenever it has one particular volume and pressure, must always have one particular temperature, and *vice versa*. Now, to apply this to the case of compressed air. To fix our ideas, let the air be contained in a cylinder, of area equal to one square foot, and ten feet long; let there be a tight-fitting piston at one end of this cylinder, and let the air be compressed by forcing this piston towards the other end, and give out its store of power by driving the piston back again. Suppose the piston to be pushed forward 5 feet, then the particles of air, which occupied the whole length of 10 feet, must re-arrange themselves so as to occupy 5 feet only. Now, it is found that if the piston be moved with extreme slowness, the particles will do this quite easily and quietly, and that the thermometer at the end of the operation will stand exactly the same as it was at the beginning; in other words, the temperature will be unchanged. Hence, the work which has been done in pushing forward the piston against the resistance of the air is all

stored up in the form of "potential energy," and none of it in the form of sensible heat. The whole of this work will therefore be available at any future time for pushing the piston back again against any resistance that may oppose its doing so. Meanwhile, the pressure gauge, at the end of the operation, will be found to indicate just double the pressure it did at the commencement. The air has thus obeyed Boyle's law, according to which the pressure increases in exact proportion to the decrease of volume,

Now, let us make the opposite assumption, namely, that the piston is moved forward with extreme quickness. Then the particles have no time to take up the new arrangement quietly, as they did in the former case. They are driven forcibly together, and thrown into violent agitation; in other woods they are heated. The thermometer will stand, at the end of the motion, considerably higher than it did at the beginning. But this is not all. The pressure will be altered, not only in virtue of the change in volume, but also in virtue of the change in temperature. Practically the pressure gauge will stand much higher at the end of the motion than it did in the former case. And if the motion be now continued, it must be continued against this increased pressure; and much more work must therefore be expended in driving the piston, say through another foot, than would be needed if the first advance had been made slowly, as in the former case. This increase of pressure, due to increase of temperature, follows at once from the kinetic theory of gases, according to which pressure is simply the average effect of the continual impacts of the vibrating particles of the gas as they strike against the surface which contains them. It is obvious that the more intense the vibration the more violent the impacts, and therefore the higher will be the pressure that represents their effects. We may illustrate the case to ourselves, very roughly, in thinking of the difference there would be in compressing one swarm of bees which were inert, and another which were all alive and buzzing. In any case the fact is certain that the rise in temperature produces a rise in pressure, and a rise which is much higher in proportion; and the work to be done in any further compression will be increased accordingly. The result will be that, supposing in both cases the piston is pushed to the same distance, say 1 foot from the further end, the amount of work stored up as power in the compressed air will be much greater in the second case of rapid or "adiabatic" compression, than in the first case of slow or "isothermal" compression. And this second case comprises nearly all practical cases, since the time allowed for compression is always very limited.

Now, granting this result, it may be asked, "What does this matter? If there is more power stored up, there is more power to be got out, and that is all." But unfortunately that is not all. It would not be all even if the power were to be drawn upon immediately. But in point of fact the only object of the process is to form a permanent reservoir of power, on which we may draw, either at a great distance from the place at which it was formed, or at a long interval after its formation. Now, in the second of our two cases, which is that of practice, the compressed air is at a high temperature, much higher than that of the atmosphere; and before its power is utilized, it must needs be that much of this heat will have been dissipated. But this loss of sensible heat means a great reduction of pressure, just as the rise in sensible heat means a great increase of pressure: and hence the power which can be got out of the air, when the time of spending comes, is much less than there was contained in it at first. But this is not all. As practically the air must be compressed rapidly, so practically it must be expanded rapidly; the one process is the converse of the other, and the converse effects follow. Hence, as the first compression raised the temperature, and so produced an increase of pressure much beyond what was due to the decrease in volume, so also the first expansion will lower the temperature, and will so produce a decrease of pressure much beyond what is due to the increase of volume. And, as the energy put into the air, in practice, is much greater than would be put in if the compression was very slow or isothermal, so the energy that can be got out of it in practice is very much less than could be

got out of it if the expansion was very slow or isothermal.

The above explanation may perhaps serve to put in a clear light the two great defects which, under practical conditions, reduce the efficiency of compressed air to a very low fraction. Possibly it may also suggest to some minds what is the tolerably obvious remedy. Since both sources of loss are due to the fact that the air does not maintain itself at the same temperature throughout the two processes, is it not possible to maintain it at that temperature by artificial means? And this is, in fact, the method which has actually been followed. The idea and its application appear to be due to the mining engineers of France and Belgium. The method usually employed has been to inject cold water in the form of fine spray into the compressing cylinder, and hot water in the same form into the expanding cylinder. Of course such a remedy is only partial. The cold water prevents the air from taking up an increased temperature, but only by becoming heated itself; and this heat cannot to any great extent be utilized. Similarly the hot water must be heated artificially, and this heat cannot itself be rendered efficient; it merely acts to diminish the loss of efficiency in the expanding air. Theory and practice, however, seem to show that this waste is not large, and moreover that it does not increase in proportion to the degree to which the compression is carried, but, on the contrary, is the same for the same amount of energy expended. Hence follows the important principle that the pressure at which compressed air should be employed should be as high as possible, since this enables the reservoir and other apparatus to be on a smaller scale, lighter, and more compact.

So far for the theory of the subject. We may next inquire how far its difficulties have been met in Colonel Beaumont's recent solution of the problem. Such as they are, they have been frankly recognized, and to some extent at least may be said to have been overcome. Colonel Beaumont has followed the French engineers in their endeavors to cool the compressed, and heat the expanding air; but instead of the spray method adopted by them, he has preferred to surround the compressing cylinders with cold water, and the expanding cylinders with steam at about atmospheric pressure. The former method has already been adopted by the Woolwich authorities, in the apparatus designed for producing the very high pressures of air required for torpedo work; and at present it is this very apparatus which is being used by Colonel Beaumont to charge his experimental engine. Probably this may have led him to adopt the parallel method of steam jacketing for the case of expansion. It is obvious that both arrangements are less complicated than the spray injection system, and, for very high pressure, have the great advantage that they occasion no additional valves or attachments to be kept tight. For this it may be well worth while to incur some additional loss of heat. In fact, air-tightness is the great feature of Colonel Beaumont's system. There seems no doubt that he has succeeded in constructing a reservoir into which air can be pumped up to a pressure of 1000 lbs. per square inch, and which will retain that pressure, practically unimpaired, for at least some hours after the operation. At present this reservoir consists of a number of strong tubes, connected by cross-pieces; but another form is now under construction, in the very capable hands of Mr. Daniel Adamson, which is to consist of a welded cylindrical vessel, 3 ft. in diameter, having only one opening for inlet and outlet. This opening is closed, we believe, by a spindle-valve with conical seating, much like an ordinary safety-valve. In any case, Colonel Beaumont must be credited with having seen the advantages to be derived from the use of high pressure, and for having overcome the obvious difficulties attending it. He has made another step in the same direction. Previous employers of very high pressure in the case of steam—*e. g.*, M. Francq., the designer of the fireless engine—have not ventured to turn the full pressure of their reservoir direct on to the face of their piston. They have employed an expander, or reducing valve, to reduce the pressure in an intermediate chamber before admitting it to the engine. It has no doubt been urged by them that, in thus expanding air or steam without doing work no energy is theoretically lost, but in practice it can hardly be doubted that such an arrangement must

produce considerable waste. Colonel Beaumont boldly turns his air at the full pressure of 1000 lbs. into his cylinders, cuts it off almost immediately, and then expands it down, using two or (as at present) three cylinders for the purpose, until he parts with it at atmospheric pressure or thereabouts. The use of these two or three cylinders, no doubt, means a certain amount of complication, and additional loss in friction, &c. The present engine has six cylinders, and the one now building will have four. But there is no reason apparent why two cylinders with cranks at right angles should not suffice, as in M. Mallet's compound locomotive, and then the suppression of the reducing valve cannot but be a step in the right direction.

But giving all possible credit to Colonel Beaumont for the advance he has made in the construction of compressed air locomotives, it still remains to ask how far his system is likely to come into practical use. Any claim on the ground of economy cannot be said as yet to be fully established. It must be remembered that, even if the loss in compression or expansion be completely avoided, there remains an important practical disadvantage, which nothing can overcome. In an air engine there are three sets of machinery which have to be actuated by the boiler steam—namely (1) the engine which works the compressing machinery; (2) the compressing machinery itself; (3) the engine which actually drives the locomotive. In an ordinary steam engine the last named stands alone. There are thus two extra mechanisms in the case of the air engine; and assuming the losses by friction, &c., in each of these to be about one-fourth, the combined efficiency will be diminished, as compared with that of a steam engine, by nearly one-half. When to these we add the losses which must always accrue in compression and expansion, we cease to be surprised that compressed air engines of the best construction do not seem as yet to have achieved in practice an efficiency—or ratio between the work indicated in the driving and in the compressing cylinder—of much more than 30 per cent. Against this Colonel Beaumont has to set two things—first, his own improvements, especially the employment of two or three times the amount of pressure which has hitherto been in use, and, secondly, the fact that his steam is generated in a stationary boiler, and the engine has condenser and all other advantages, and thus far more economically than in the boiler of an ordinary locomotive. Now as to the first claim, we have not as yet the data for estimating its value. As already mentioned, the air for the experimental engine is compressed by the torpedo apparatus at Woolwich, which is a small one, so that the operation takes some hours. In actual work, there is to be a large stationary reservoir always maintained at the full pressure, and having about ten times the capacity of each engine reservoir; and from this the latter will be filled as required by simply making a connection, and with great rapidity. In this process the air will not be doing any work, and the loss due to expansion will doubtless be very small. When this system is fairly started, and not till then, the efficiency of the Beaumont engine will become matter of calculation. As to the second claim, there is no doubt considerable weight in it, but it may be pushed too far. No refinements in apparatus or construction have yet succeeded in reducing the consumption in the best condensing engines much below $1\frac{3}{4}$ lbs. of coal per horse-power per hour. According to Mr. D. K. Clark, the consumption in a good locomotive does not so very greatly exceed this. And although the tramway engine of the future—with which the Beaumont engine must be compared—will be much smaller, and therefore probably less efficient than a locomotive, and on the other hand will not be a condensing engine, yet we think it may be safely asserted that it will be a compound engine, after the type introduced so successfully by M. Mallet on the Biarritz Railway. Recent investigations go to show that for small engines and low speeds the economy of compounding is incontestable, whatever it may be for main line locomotives. Now with a compound portable engine, of very much the same dimensions; and without steam jackets, &c., Mr. Daniel has brought down the consumption of coal below 3 lbs. per horse power per hour. It would appear, therefore, that an economy of 50 per cent. in fuel is the utmost

that can be looked for by the adoption of the compressed air system with stationary boilers, and this will certainly fail to outweigh the serious losses we have already described above.

Probably Colonel Beaumont would not, on the whole, be wise to dwell much on the superiority of his system as far as mere economy of fuel is concerned. But there are several practical advantages which, even for ordinary tramways, he may fairly allege. As against the common locomotive he gets rid of all smoke, all fire, all smell, nearly all noise, all fear of explosion from shortness of water or other neglect, all danger from tubes leaking, feed valves sticking, &c. As against both this and the fireless or hot water locomotive, he gets rid of steam, and with it of the whole difficulty and nuisance of a condenser. Moreover, should an accident occur, there will be no outbursts of scalding steam to spread devastation around. He will also effect an important economy in dead weight, by substituting air for water as the medium in which the power is stored. These are advantages which, even for ordinary tramways, may fairly be set against a moderate increase in the mere consumption of fuel. But there are some cases where these advantages assume an importance quite overwhelming. Such are ordinary mines, where steam and heat are generally forbidden, and where compressed air is already in many instances the recognized motive power; such are underground railways, like those of London; such, above all, are long tunnels, like those of the Alps. The St. Gothard tunnel is a typical example. The whole machinery for supplying the power, including waterfalls, turbines, and air compressors, is there ready on the spot at each end of the tunnel; the engine would merely have to connect itself with this in order to receive its charge, which it would afterwards give out in its passage underground, to the benefit, and not to the annoyance, of the passengers. Here, therefore, there would seem to be a legitimate field for such a system as Colonel Beaumont's, and before long we hope to hear that in this application at least it has obtained such success as it deserves

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RACK RAILWAY WORKED BY ENDLESS ROPES, FOR STEEP INCLINES.

By T. AGUDIO.

From Selected Papers of the Institution of Civil Engineers.

The plan invented by the author is intended for railways in mountainous districts, for working inclines of 1 in 10, or even steeper, and with curves as sharp as 500 feet radius. This is accomplished by a central rack-rail, and a propelling car or "locomotor," fitted with horizontal driving pinions gearing into each side of the double-faced rack. The ample water power available in such localities is utilized through turbines driving a pair of endless ropes, by which the driving power is communicated to the locomotor.

The turbines, situated conveniently near the foot of the incline, are geared to a pair of main grooved driving pulleys; whence each of the endless driving ropes, after passing round a tightening sheave loaded by a weight, is led up the incline, one on each side of the line, supported at suitable intervals on carrying sheaves, with inclined guide sheaves round the curves. In its course each rope passes also round a pair of large vertical driving pulleys on each side of the locomotor, which drive through friction clutches and miter wheels, the two pairs of horizontal pinions gearing into the rack-rail. At the top of the incline the ropes pass round vertical guide sheaves; and thence return to the foot of the incline by any shorter and more direct cut that is practicable, instead of following the windings of the railway. These endless ropes are accordingly employed, not as ordinarily for direct haulage of the train on the incline, whereby the full strain of the load would be thrown wholly upon them, but as

quick-running driving ropes, for communicating the driving power from the turbines to the propelling mechanism of the locomotor, whereby the strain on the ropes is reduced below that of the load, in proportion as their speed is higher than that of the train. In ascending, the train is pushed up from behind by the locomotor in the rear, and in descending is held in check by it in the front. The locomotor being always at the lower end of the train on the incline, all risk of accident through breakage of drawbars is obviated.

This plan was first tested experimentally in 1862, on the old Dusino incline of the Turin and Alessandria railway—a portion of the line which had been abandoned, owing to the steepness of the gradient, the sharpness of the curves, and the bad ground. The ropes were here driven by steam power; and trials in comparison with coupled locomotives of special construction showed a superiority of 50 per cent. and upwards in favor of the Agudio system. The report in 1864 of the late M. Charles Couche, one of the French commission appointed to investigate the Dusino experiments, was highly favorable to the plan, and he recommended it as deserving of the utmost encouragement from the French government, as it presented such important and indisputable practical advantages over locomotive working, and formed a novel and efficacious expedient for surmounting the natural obstacles encountered in mountainous districts.

Upon the further recommendation of M. Couche, a practical trial of the plan on a larger scale was authorized in 1868. The site selected was on the French slope of Mt. Cenis, where the construction was commenced of an incline of excessive steepness, rising from the valley of the Arc, near Lanslebourg, to nearly the summit of the ridge. The works were interrupted during the Franco-German war, but were resumed in 1872; and the incline was opened for working in 1874, having a length of 1463 yards, or 0.83 mile, and a rise of 1150 feet, from 4730 to 5880 feet above sea-level. The average gradient was thus 1 in 3.82, or 26 per cent., the steepest part being 1 in 3.14, or 31.8 per cent. The incline was laid with a single line of rails, of the ordinary 4 feet $8\frac{1}{2}$ inches gauge, with the rack fixed midway between them.

The rack was made in 2 feet lengths, out of a single flat bar of steel, of $4\frac{3}{8}$ inches $\times$ $\frac{1}{2}$ inch section and 6 feet in length, which was crimped or corrugated transversely while hot in accurately shaped dies under a hydraulic press, so as to form a double rack of 4 inches pitch, and $4\frac{3}{8}$ inches width and height. It was placed on edge, so that the rack teeth facing towards either side were the spaces facing towards the other. These 2 feet lengths were riveted up in sets of three, between the top and bottom bars of shallow channel-iron, each $4\frac{3}{8}$ inches wide by $\frac{5}{16}$ inch thick; and the 6 feet lengths thus formed were strongly bolted down upon a center longitudinal sleeper. The rack was made at the works of Messrs. Brunon, Rive-de-Gier, France; its construction elicted high approbation, and is seen to be much superior in point of safety to the Rigi rack, which is nothing else than a ladder.

The pair of turbines at the foot of the incline were 6 feet in diameter, with 450 feet head of water, and combined nominal power of 900 H.P. They ran usually at two hundred and fifty revolutions per minute, and were geared 5 to 1 to the main driving pulleys of 13 feet diameter, giving a speed of 34 feet per second, or 23 miles per hour, to the ropes. These were $\frac{7}{8}$ inch in diameter, of steel wire with hemp core, and weighed 3 lbs. per yard. The strain upon each rope in working never exceeded 2 tons total, or 8 tons per square inch of metallic section. The direction of running was upwards along the incline. The driving power was communicated by their simple adhesion in the grooves of the main driving pulleys and of the locomotor pulleys. The locomotor traveled at one-fifth the speed of the ropes, ascending the incline, therefore, at nearly 7 feet per second, or 5 miles an hour. The pulleys were put in gear with the horizontal driving pinions through friction clutches, for starting the locomotor gradually. With the four pinions working into the rack-rail there were always four teeth in gear, dividing the propelling thrust among them, instead of the whole thrust coming upon a single tooth of a rack having only one pinion gearing into it.

The plain rims of the pinions bore against the flanges of the channel iron bar forming the top of the rack-rail, and thus steadied the locomotor laterally, in conjunction with the flanges on the four carrying wheels. During the ascent four safety-pawls, or catches, clicked into the rack-rail, for scotching the locomotor instantly in the event of accident.

The descent being made by gravity alone, the ropes remained stationary, and the speed was controlled by three powerful brakes upon each locomotor, of which there were two. The first brake applied on starting to descend, and kept on throughout the descent, was a long skid or slipper brake, gripping tightly between its strong jaws the longitudinal sleeper of the rack-rail; the sides of the sleeper were faced with iron bars for the skid to slide against. If more brake power was required, a pair of wood brake-blocks were applied, in one of the locomotors, against a drum on the shaft of each horizontal driving pinion. In the other, a hydraulic brake was employed, somewhat on the dash-pot principle. Each pinion-shaft was cranked, and worked a piston in a water cylinder, with a passage communicating from one end of the cylinder to the other. By throttling this passage to half the area, a powerful resistance was opposed to the rotation of the pinions gearing into the rack-rail. A third resource for retarding the descent was supplied in each locomotor by a pair of vice-plates, between which the rims of the rope-pulleys were gripped laterally, for bringing into play the brake action available from the slipping of the ropes round the pulleys. The second source of brake power was employed sparingly and with great caution, to avoid straining the driving gear; while with the third this was still more stringently the case, to avoid wear of the ropes.

Towards the end of the year 1875, elaborate experiments on the working of the Lanslebourg incline were conducted for more than three months by a commission of the Italian and French governments and of the Eastern Railway of France. During that period the ascent of the 1150 feet rise was regularly performed, with heavy loads, at a speed of about five miles an hour; and the trains were stopped and started at pleasure at any point upon the incline with the utmost readiness and without the slightest jerk. By means of a Prony-friction brake upon the shaft of the rope driving pulleys at the turbines, it was ascertained that the power required for driving the pair of ropes alone, when running empty, amounted to 100 HP.; the locomotor, weighing 12 tons, took $239-100=139$ HP.; and a train of 24 tons, exclusive of the locomotor, required $438-239=199$ HP. The useful effect was therefore $\frac{199}{438}=45$ per cent.; which seemed to the Italian commissioners so much higher than likely, that they reduced it to 38 per cent. by calculating the several resistances of the train from the data furnished by the regular working of ordinary railways.

In a letter addressed last year by Signor Agudio to the Italian parliament, he points out that, even taking the lower figure of 38 per cent. for the above useful effect, this would be equivalent to at least 50 per cent. on an incline of only 1 in 10, less power being then absorbed in raising the dead weight of the locomotor itself. Moreover the old large wagons, out of use, that were lent for the experimental trains, had a wheel-base of no less than 11.8 feet, which was ill-suited to curves of only 500 feet radius; hence the co-efficient of tractive resistance adopted by the commissioners, of only 0.00386, or 8.6 lbs. per ton of load, is far too low; and upon half the length of the incline the resistance must have amounted to ten times as much. For the cheaper construction, too, of the incline, second-hand timber, much damaged, had been procured from the previous Fell railway in that locality. The consequent want of steadiness in the structure, together with the lateral oscillations of the train, contributed to increased friction between the driving pinions and the rack-rail. The commissioners' calculations, again, were based on their earliest experiments, in which the weight of the whole train did not exceed 36 tons, including the locomotor, and the speed was only $6\frac{1}{2}$ feet per second, or $4\frac{1}{2}$ miles an hour; while later on, ten journeys a day were performed with trains of 45 tons total, at a uniform speed of $7\frac{1}{2}$ feet per second, or $5\frac{1}{8}$ miles an hour, both in ascending and in descending. On all accounts, therefore,

the author considers it would be fairer, while safely within the mark, to take 52 per cent. as the useful effect on the incline of 1 in 3.82; which corresponds to 63 per cent. on an incline of only 1 in 10.

The commissioners from the Eastern Railway of France included in their report an estimate of the superiority of the Agudio system over their own most powerful locomotives with eight coupled wheels, working up the steepest gradient practicable, say 1 in 40. The useful effect of those engines is calculated from their coal consumption at 20 per cent. as a maximum; while that of the Agudio system, calculated from its water consumption, is $38 \times 0.80 = 30$ per cent. as a minimum, the turbines utilizing 80 per cent. of the water power expended. An equal expenditure of power would convey 1.8 time as much load up the rack incline as up the locomotive gradient, while the capital outlay on works and plant would be only one quarter as great; hence the Agudio system is estimated to be altogether 7.2 times the more economical.

The advantages of this system for an incline of 1 in 10 are summed up by the author as follows:

1. Nearly twice as much traffic can be worked in a given time as by locomotives.

2. The capital outlay required is little more than one-third. (The French estimate just quoted of only one-quarter was for the steeper gradient of 1 in 3.82.)

3. No inconvenience or delay is occasioned to the working of the regular trains; on the contrary, they would be conveyed up an equal height in little more than half the time and with greater safety.

4. The working expenses are greatly reduced, as the incline of 1 in 10 is only a quarter the length of a locomotive gradient of 1 in 40, and the use of water power saves all consumption of fuel.

5. Steeper mountain slopes can be ascended, and the summit tunnel through the ridge can thus be considerably shortened, or even done away with altogether under favorable conditions of climate and ground.

In a further letter to the Italian Minister of Public Works, Signor Agudio disposes of the objections to the adoption of his system in connection with ordinary lines of railway. He explains in detail the mode of working trains at the junction stations at the top and bottom of the incline, the propelling car there taking its place at the lower end of the train, while the locomotive shunts off into a siding. The rack-rail, standing its own height above the ordinary rails, is made with a tongue to open, like an ordinary switch, where it crosses the main line rail at the junction; while the rope there drops into a narrow slot crossing each of the main line rails obliquely. The propelling car is enabled to run backwards as readily as forwards on the level landings at the top and bottom of the incline, by providing it with an ordinary reversing clutch in the driving gear, the ropes continuing to run always in the same direction, upwards along the incline. For working regularly trains of 180 tons useful load, a steel wire rope weighing 3 lbs. per yard, and running at the same speed as at Lanslebourg, would suffice for a rise of about 2300 feet, which would give nearly 4½ miles length for an incline of 1 in 10. Without any reduction of load, a slight increase in the size of the rope or in the speed of running would allow of the incline being extended to 6 miles, thus giving a rising of 3000 feet. The system thus lends itself with great readiness to the various requirements of railway routes. As the ropes do not act by direct haulage, but drive by simple adhesion in the groove of the locomotor pulleys and through a friction clutch, any sudden increase of train resistance throws no severe strain upon the ropes, but merely causes them momentarily to slip on the pulleys at the first instant; and the slipping then transfers itself immediately to the friction clutch, which is adjusted beforehand to slip whenever the pull upon the ropes rises only 10 per cent. above their normal tension in regular working. Repeated experiments equivalent to actual breakage of the ropes at Lanslebourg showed that the ascending trains were instantly scotched dead at any point on the incline, by the four catches clicking into the rack-rail, without any occasion to apply the brakes. Failure of one of the pair of ropes would not delay passenger trains, which

could be worked by the other rope singly while the broken rope was being spliced.

Signor Agudio urges the adoption of his system for the ascent of Tivoli, about 16 miles from Rome, on the projected Rome, Aquila and Solmona railway where a short cut can be made by a rack-rail incline of only $1\frac{1}{4}$ mile length, with a ruling gradient of 1 in 10, and curves not sharper than 1,000 ft. radius, in place of a loup five and a half times as long, which would be required for the proposed locomotive gradient of 1 in 70, the total rise being 500 feet. The cost of the work is estimated at about £20,000 for the entire construction of the incline, laid with a single line of rails of 4 feet $8\frac{1}{2}$ inches gauge, with the rack-rail between them; £2,400 for two pairs of steel wire ropes weighing 3 lbs. per yard, one pair to be kept in reserve; £8,400 for driving pulleys, tightening, guiding, and carrying sheaves, &c., with a sufficient supply of duplicates in reserve; £5,000 for three 12-ton locomotors; and £10,000 for the hydraulic power, including two pairs of turbines of 1,000 HP. in the aggregate, one pair to be in reserve for emergencies. Adding for contingencies and superintendence, &c., the total estimate amounts roundly to about £56,000. Trains of 180 tons would make the ascent or descent of the incline in ten minutes. By the adoption of similar inclines at other points on the same line of railway of 100 miles in length, 30 miles might easily be saved out of the heavier portions of the works, and shorter tunnels would suffice.

WATER SUPPLY.

From "Nature."

Among the improvements in sanitary matters that this generation has witnessed not one ranks higher than the settled and still growing conviction of the importance of a pure water supply; and nowhere are the various aspects of the question more keenly debated and considered than in the Metropolis at the present time.

At a discussion at a recent meeting of the Chemical Society there seems to have been some doubt thrown on the conclusions arrived at by chemists in determining the wholesomeness of a water, by no less an authority than Prof. Huxley, and it may be well to inquire how far his allegations are borne out by facts.

In the earlier days of the history of chemistry, as was to be expected, the processes adopted in the analysis of water were crude in the extreme, and the quaint ideas promulgated in the treatises then published are not a little amusing. Gradually, however, and especially during the last few years, the methods of analysis have improved, and although, judging by the wide diversities of opinion that exists as to what may or may not be pronounced a water sufficiently pure for drinking purposes, the subject cannot yet be said to have arrived at a stage completely satisfactory; still, so far as the purely chemical evidence is concerned, it would seem to be able to furnish results which are sufficiently exact for all practical purposes. The operations involved are among the simplest and easiest the chemist has to perform, and consequently it is not the data furnished by analysis that are called in question, but the conclusions drawn from them.

Persons interested in sanitary questions, but who have no special knowledge of the difficulties that beset the forming a correct judgment as to the wholesomeness of water, are apt to express themselves as scandalized, and it must be confessed with some show of reason, that it should be possible there should be so little agreement amongst those who are looked up to as authorities on such matters.

This disagreement, however, is more or less inevitable in the present state of our knowledge, and is largely due to the intricacy of some of the problems involved in the question, which is by no means a simple chemical one.

The debatable ground is the nature and estimation of organic matter, and the amount of significance that should

be attached to the presence of oxydized nitrogen compounds.

Organic matter may be of animal or vegetable origin, the former being dangerous and the latter much less so, if, indeed, it be not altogether innocuous. To distinguish between the two kinds is therefore all important; but unfortunately it is impossible directly to do this, as both animals and vegetables yield albuminoïd matters, which are, chemically speaking, practically identical in composition.

Of the various processes for the estimation of organic matter there are three that are in general use. One, the oldest, known as the permanganate process, finds its advocate in the present day in Dr. Tidy, and consists in measuring the organic matter by the quantity of oxygen required to oxydize it. Another, originated by Prof. Wanklyn, and which he calls the albuminoid-ammonia process, consists in decomposing the organic matter by an alkaline solution of potassium permanganate, and taking the resulting ammonia as the measure of the organic matter. The third process, the one employed in the laboratory of the Rivers Pollution Commissioners and advocated by Dr. Frankland, its originator, estimates the organic carbon and nitrogen separately.

A good deal may be said in favor of all these processes, as affording a rough estimation of the quantity of organic matter, but none of them can be relied upon as giving any indication of its nature, *i. e.*, as to whether it is dangerous or not; and yet it is the almost invariable custom to judge of a water by the quantity of organic matter it contains, no matter what its origin, and a variation of two or three times a given amount is held to make the difference between a good and a bad water.

It was to this point that Prof. Huxley especially addressed himself in his remarks already referred to. He gave it as his opinion, speaking as a biologist, "that a water may be as pure as can be as regards chemical analysis, and yet, as regards the human body, be as deadly as prussic acid, and on the other hand may be chemically gross and yet do no harm to any one." "I am aware," said he, "that chemists may consider this as a terrible conclusion, but it is true, and if the public are guided by percentages alone they may often be led astray. The real value of a determination of the quantity of organic impurity in a water is, that by it a very shrewd notion can be obtained as to what has had access to that water."

However startling these statements may be to those who judge of the wholesomeness of a water by the amount of organic matter it may contain, we believe it to be none the less an accurate description of facts. It is within our knowledge that some of our most wholesome supplies sometimes contain an excess of organic matter, and that the waters which give rise to typhoid fever, and other hardly less serious disorders, are frequently just those which contain the least, the difference of course being that in the one case the organic matter is innocuous, in the other deadly.

Since, then, chemical analysis fails entirely to distinguish between these two kinds of matter, it may be thought to be a work of supererogation to have recourse to it at all. Not so, however, for what analysis fails to do directly it can to a large extent do indirectly. Organic matter in solution in water is more or less prone to oxydation, the highly putrescible matter of sewage being most so, and that derived from vegetation very much less so. Hence it follows that one would expect to find the oxydized nitrogen compounds in greater excess in the one case than in the other, and as a matter of fact that is just what we do find. Almost invariably, in all waters of acknowledged wholesomeness, the quantity of nitrates never exceeds a certain small amount, whereas in waters, such as polluted well and spring waters, that have given rise to illness, the oxydized nitrogen compounds, with other accompaniments of sewage, are to be found in excess. By means then of these oxydized nitrogen compounds we get collateral evidence throwing light on the nature and probable source of the contamination, of which a mere percentage estimation of organic matter would fail to give the slightest indication.

The mistake has been hitherto, that the discussion has been narrowed by looking at the question almost entirely from a chemist's point of view. It is, however, to the biologist that we must look

chiefly for the future elucidation of the subject, and he has a field of the widest range, embracing much untrodden ground, for his investigations.

Putting on one side the specific poisons which, through the medium of water are able each to generate, after its kind, diseases such as typhoid fever, it is highly probable, judging from what has already been proved to take place in analogous cases, that dangerous organic matter is not poisonous as such, but acts by affording the pabulum for organisms which are able to set up putrefactive changes in the blood of the person drinking polluted water. Even the conversion of organic matter into nitrates is not a mere chemical process of oxydation, since we now know that the oxydation only takes place by the help of a distinct ferment.

In the inquiry as to how far organic matter is destroyed in rivers, it is clearly insufficient to rely upon laboratory experiments in which diluted sewage is exposed only to the oxydizing influence of air. This is entirely to ignore the agency of vegetation and of the vast army of organisms, identical with or allied to bacteria, which, being endowed with various functions of reorganization, convert the carbon and nitrogen of organic matter into simpler inorganic compounds, these in turn to become the food of the more highly organized aquatic vegetation.

Whilst therefore duly recognizing the practical help that chemistry can afford in the more limited scope that properly belongs to it, we trust, in the interest of sanitary science, that the enunciation of the views of so distinguished a biologist as Prof. Huxley may have their due weight with those to whom these questions are ordinarily referred, and will tend to promote a better understanding and more solid ground for agreement than has up to the present seemed possible.

THE IRON CRISIS AND ITS LESSON.

From "Iron."

At a time when the iron industry, by far the most important of English manufactures, seems fast relapsing (notwithstanding fitful gleams of activity) into the critical position out of which it only emerged some eight months ago, it is clearly well worth our while to attentively examine our position and see if there is any prospect of mending it.

We have had more than enough of rosy prospects and pæans over the good things that are to come in the future, but are unable to fill the exchequer in the present. The most mischievous things in the world are agreeable illusions, and the best service is to expose them promptly. That we can look to any concurrence of favorable circumstances bringing about a proximate renewal of the brief season of prosperity and high prices, which came upon us with bounds and "booms" in the latter part of last year, seems to the unbiased observer in the highest degree improbable. America has been lately looked to as being, and likely to continue to be, our best customer for iron and steel, and the American demand is the sheet-anchor of our optimists; but that the working blast-furnace capacity of America, with her 400 furnaces in blast, is now very nearly, if not quite, abreast of all possible demands from American iron consumers seems indisputable; while it is also pretty clear that the Bessemer and open-hearth steel production of the United States will, in 1881, be not far, if at all, short of fifteen hundred thousand tons. The works of the Pittsburgh Steel Company and the St. Louis Works, with the extensions of the North Chicago, Scranton, Pennsylvania and the Edgar Thompson Companies will, without the new open-hearth plants now building, be alone equal to an increased product of at least 300,000, and probably 400,000, tons of steel a year, while the new open-hearth furnaces will add a further 250,000 tons to the supply, so that clearly this is not an exaggerated estimate. Now the rail requirements of the States for 1880-1881

are not, by the most competent observers, expected to exceed 1,400,000 tons. It is therefore evident that, unless some new feature arises in the calculation, there is not much to be hoped for in the way of rail orders from the States during the coming year. Certainly the demand for iron rails will not be renewed. There remain only the home, European and colonial markets. But here we are brought face to face with another danger. We have been so long accustomed to consider our position as makers of cheap iron and steel unassailable, that we have perhaps allowed ourselves to slacken speed in the technical race, while our opponents have been straining every nerve to cheapen production, and availing themselves of every improvement that holds out a promise of economical results. It is certain that unless we bestir ourselves we may find Continental steelmakers underselling us in neutral markets to a far greater extent than has hitherto been regarded as possible. In Italy and Spain and Holland we have already had to encounter severe competition from German and Belgian and even French makers. Let us by all means open up new markets in China and Japan, Turkey and Persia; but while thus going far afield it will not do to neglect what is nearer home. If the iron trade of England is to regain a position of prosperity it must, before all, devote itself to economy in production, and not sit quietly by and trust to Providence and a rise in the markets. In pig-iron making, it is generally admitted that, in our newer districts at least, such as Cleveland, we are in the front rank for technical and economical efficiency; though, even here, the Americans, with their 1100 tons per furnace per week have surpassed anything we have yet done, and the Eastern France and Belgian and German makers are pushing ahead both in outputs, such as the 750 tons per furnace per week which is not uncommon in Luxembourg, and in economy of fuel. There are now several districts in Europe where pig is made as cheaply as in Cleveland, and that to the amount of some hundreds of thousands of tons per annum. It must, however, be admitted that the margin for economizing in blast-furnace practice is not large, and that, with the general adoption of the regenerative stove, we are doing much to minimize that margin. When we come, however, to the conversion of pig iron into malleable products, the matter is quite otherwise. At the present time it is best boldly to face the fact that the main, if not the only, direction in which economy of manufacture is to be looked for is in the substitution of steel for iron in every department. It cannot be too clearly under stood that with modern appliances, which admit of readily producing from a pair of Bessemer vessels 80,000 to 150,000 tons a year, or with a pair of large Siemens or Pernot furnaces 20,000 tons a year, it is very much cheaper to convert a ton of pig into steel or ingot iron than into puddled iron. The elements of the calculation are simple. The two great factors of cost in the conversion of pig into malleable iron are labor and fuel. In each of these items the costs of a well-appointed Bessemer work, with a good system of boilers and economical engines, are far less than half of those of a puddling furnace. The fuel consumed in the Bessemer process is indeed a mere fraction of that consumed in puddling, while the resulting metal is unquestionably far better for every purpose than anything that can be turned out by the puddler. Yet we find almost every one of our leading competitors doing more—taking account of their crude iron manufacturing capacity—than ourselves, in substituting steel plant for the wasteful and obsolete puddling furnace. To illustrate this we may take the case of America, France, Belgium and Germany. The make of pig iron in 1879 in the United States was about 2,700,000 tons. The capacity of their new steel plant, according to Mr. Swank, is 570,000 tons, of which 330,000 will be Bessemer. In other words, their new Bessemer steel plant is now capable of dealing with one-eighth of their total production of pig iron. Moreover, their total steel-making capacity for 1881 will be (as we have seen) at least 1,500,000 tons, that is, they can more than convert half of their total pig production into steel.

In France the new Bessemer works of Longwy, de Wendel, Denain and the Meuse, alone will have a capacity of 200,000 tons, without reckoning the

large open-hearth extensions at St. Chamond, Terrenoire, and elsewhere. But the total product of pig iron in France is only 1,300,000 tons, so that our neighbors, at whose claims to be a great and enterprising iron making people we are accustomed to sneer, are preparing for the change by building new Bessemer works, which will take at least a seventh of their total make of crude iron. Belgium is erecting new Bessemer plant which will have a capacity of over 100,000 tons, or say one-fourth of her total makes of pig iron. Lastly, notwithstanding the almost crushing disasters which overtook her iron trade two years ago, we have Germany, with a pig-iron production of 1,900,000 tons, not only increasing her open-hearth capacity, but building at least four new Bessemer works, to work up her cheap phosphoric irons into steel. The capacity of these works may be taken as at least 150,000 tons, which represents about one-twelfth of her pig-iron production. In England we have four new vessels building at Bolckow, Vaughan's works, two at Erimus, and two at Darlington, and one at Rhymney, with a total capacity, according to Mr. Jeans, of say 155,000 tons—we do not count the Carnforth plant, which is really an old one, though it has never been at work. The same remark indeed also applies to the Darlington plant, which is actually only a part of Bolckow-Vaughan's old Gorton plant, and is therefore not a real addition to our steel works, but merely a change of locality of an old work. This correction reduces the productive capacity of our new Bessemer plant to 125,000 tons, or in other words our new Bessemer plant will not convert one-fiftieth of our total make of over six and a quarter million tons of pig.

It is therefore clear that of all great ironmaking countries, we are at present the slowest in enlarging our productive capacity by the most economical and advantageous of all metallurgical processes. In fact, even Austria, with her four new ten-ton converters, which alone could convert at least a seventh of her make of crude iron, is far ahead of us in enterprise. But it may be urged that our existing Bessemer plant was far from being utilized in 1879, and why then should we build more; and secondly, that the large initial expenditure to erect a Bessemer plant is a serious obstacle when the profits of the trade are so precarious and small, and trade is so bad as it is at present. Both these seemingly plausible pleas, however, are fallacious. The existing British Bessemer plant that was not fully used in 1879, was only not used because it was old and badly arranged or badly placed. No better evidence of this can be afforded than the fact that the idle plants were, with one exception, those of the earlier days of the Bessemer industry, when two hundred tons per pit per week was thought an enormous output, and all arrangements were made in accordance with that view. To expect a Bessemer plant built more than a dozen years ago to compete successfully with those of to-day, when we consider the enormous progress the Bessemer process has made in the interval, would be utterly unreasonable. It is therefore not to be wondered at that some of the old plants with their three or four hundred tons per week capacity, should have been withdrawn from competition with the more modern plants which, casting comparatively little more, have four times their capacity. A modern ten-ton Bessemer plant of the Holley type, costing from £30,000 to £45,000, according to locality, has been proved capable of producing at least 140,000 tons a year, and would probably make much more, and is without question the cheapest iron making plant in the world. Forty thousand pounds seems a large sum, but when we find the interest and sinking fund on this capital outlay amounts to less than ninepence per ton on our product, while it appears in addition that the ironmaking value of each man and each ton of coal is increased many fold in comparison with its utmost possible effect in puddling, we see what the President of the Iron and Steel Institute means by his assertion that the Bessemer vessel is the cheapest converting apparatus in the world. There is, however, one other limitation which has hitherto done more than anything else to arrest the progress of steelmaking, and that has been the presence of phosphorus. So long as we were confined to the use of an insignificant fraction of our pig iron for steelmaking there was

an obvious limit to expansion. But the final complete success of the Thomas-Gilchrist dephosphorizing process has removed the last bar to an indefinite extension of our steel trade; and, if we would not meet the fate of laggards in the industrial race, we must make haste to bring our steel producing capacity into closer approximation with our crude iron production. That we have sufficient ground for assuming that the lime process is an economical success, as well as a technical one, will probably be recognized by those who have learnt from our foreign columns from week to week the remarkable development which this process has attained on the continent—where, after a protracted trial at five of the leading Continental works, not only have these finally adopted it, but at least seven or eight new works are being built for its employment. Whether, as its extreme advocates assert, it will cost no more than the ordinary Bessemer process, or whether, as its interested opponents maintain, the actual working costs will exceed by seven or eight shillings the normal Bessemer costs, does not much signify for our purpose; since it is clear that, for the past twenty years, the difference between hematite and phosphoric pig has always exceeded thirteen shillings, and averaged about thirty shillings. We have specially mentioned the Thomas-Gilchrist process because it is, as far as we know, the only direct dephosphorizing process, which has obtained any success at all; certainly no other has so far been employed for the manufacture of over 20,000 tons of steel. The Krupp or Bell process has, however, of the indirect processes, though not applicable to the Bessemer operation, in preparing pig for treatment in the open-hearth furnace—obtained a certain degree of development and success. It appears, however, that it has been entirely abandoned in Europe, though it is, or speedily will be, in work in America. It will be interesting to observe the relative success of the direct-*lime* (or Thomas-Gilchrist) Siemens process, which, we understand, has already been practiced considerably in France, and will soon be in operation in America and England; and the indirect-*ore* or Bell-Krupp-Siemens process, which will unquestionably have a fair trial in the States, under Mr. Holley's auspices. How great is the confidence of French ironmasters in the technical future of dephosphorizing is shown by the fact, announced by us some weeks since, that M. Schneider and his associates, whose experience of the lime process is very considerable, they being, we believe, among Mr. Thomas' earliest licensees on the Continent, have already contracted for delivering nearly a quarter of million of tons of steel rails, the greater part of which must necessarily be of dephosphorized steel. It is not, however, into rails only (or even chiefly), but into angles, plates, girders, and merchant iron of every description, that we must look to transforming our steel. It is very certain that for all these purposes steel, and cheap steel, will be wanted in immense quantities, and iron will not be accepted by foreign customers, if Continental and American makers are able to supply them in steel cheaper and better than we can in iron. Unless we wish to sink as ironmakers to the position of hewers of coal and makers of pig iron for other nations, and nothing more, we must speedily recognize, in a practical English way, the fact that steel is not only superior to iron, but, when made by good plant on a good system, also cheaper to produce. This we take to be the lesson of the times, and the sooner we master it the better.

The Forth Bridge.—Operations are proceeding rapidly for the erection of the Forth Bridge. Workmen are engaged on Inchgarvie erecting a brick and concrete platform, on which to place instruments for the purpose of making accurate measurements of the heights, widths and depths of the various works connected with the undertaking. At South Queensferry the contractor is constructing enormous engineering, iron-founding, and fitting workshops, in which steam cranes and other powerful appliances will be placed. These "shops" are connected with the railway by means of a branch-line. The proprietors of houses, ground, &c., on the line of the bridge and railways have been served with notices to lodge their claims for compensation within twenty-one days. On the north side of the Forth matters are progressing.

THE TRAVELING OF SEA BEACHES.

By GEORGE HENRY KINAHAN, M. R. I. A.

From Selected Papers of the Institution of Civil Engineers.

Two of the chief points of controversy as regards this subject are: 1st. Whether wind waves or tidal currents are the principal moving agents in the traveling of sea beaches? and 2d, Whether large stones can be carried by ordinary ocean currents in deep water? During the last twenty years the author has had opportunities of observing the Irish Sea beaches, and especially during the last six years, while stationed in the counties of Wexford and Wicklow. The following is a digest of the results of his observations: Off the south coast of Ireland the flow wave runs eastward, and off the east coast northward. The flow-tide generates three classes of on-shore currents: 1st, on-shore currents running in a direction generally similar to that of the flow-tide wave; 2nd, counter tides, or on-shore currents, flowing in a contrary direction to that of the flow-tide wave; and 3rd, half counter-tides, or on-shore currents, generated at many of the headlands a few hours before high water. In some places the half counter-tides may run in a contrary direction to the normal currents, and in other places to the counter tides. All these on-shore currents, especially the latter, carry the beaches with them under ordinary circumstances.

The wind waves are of two kinds, viz., ground swells, or waves generated in the Atlantic or Channel, and waves due to the winds blowing directly on the coast. Their effects are either to pile up and fill the beaches, or to cut them out. The ordinary wind waves assist the flow-tide currents when they are going in the same, or nearly the same, direction with those currents. If they strike the beach at a right angle, or nearly so, they pile it up, forming "fulls" and "storm beaches"; while, if they are coming in a more or less opposite direction, they cut out the beach. On the east coast, winds blowing from any points between S. and E. S. E. by E. accelerate the traveling of the beach. From E. S. E. by E. to E. N. E. the beach is piled up; while between E. N. E. by E. and N. the beach is cut out. The cutting out is due to the dancing waves generated by the meeting of the tidal current and the wind waves. These toss and churn up the sand and other detritus, causing it to be carried out by the backwash into deep water. Continuous heavy winds in the same direction as the flow-tide currents will accelerate the carriage of a beach to such a degree that every particle of it may be carried with the tide: thus leaving the up-stream portion of a beach empty, while a "full" is formed at the down-stream end. Ground swells act differently from ordinary wind waves, as they break on the coast line perpendicularly, or nearly so, with an undulating or rolling motion, which generates a considerable suck or backwash, that cuts out the beaches.

The following is a summary of the general effects of the winds on the beaches of the east coast, between Carnsore and Dalkey:

W. and S. W. winds generate ground swells, which usually cut out the beaches. In places they drift the sand from the land out to sea or on to the beaches.

S. winds in places cause "fulls" at the northern ends of the strands, due partly to the rapid carriage northward of the beach, and partly to the land driftage of the sand, &c. They often generate ground swells.

S. E. winds carry away the southern ends of the beaches to fill them in at the northern end. At Poulduff (Cahore), it is said two strong twelve-hour gales are sufficient to cut out and carry north the "fulls" south and north of the pier.

E. S. E. by E. to E. N. E. by E. winds generally heap up the beaches. In places, however, on account of being oblique to the direction of the flow-tide current, they in part cut out, forming transverse ridges on the beach. The flow-tide waves drive up detritus to strand it, while the wind waves suck it out. To form this class of beach the wind waves are not so effective as the

tidal current, and the detritus is more stranded than removed; so that while the wind lasts the strand fills.

N. E. winds cut out the northern portions of the beaches, while they sometimes "full" the beaches to the southward. The most remarkable "fulls" due to these winds were in the small bay to the southwest of Kilmichael Point, and the "storm beaches" in the Wicklow and Bray strands. In the first locality, after continuous winds from the northeastward during the spring of 1876, a foreshore was formed over 200 yards wide, at the base of a cliff, where during the previous winter there was deep water.

With N. winds, no direct influence was observed, except that they seemed to retard the flow of the tide up the Irish Sea.

These results are connected solely with the normal currents flowing in a nearly similar direction to the flow-tide wave. With the counter tides and half counter tides the results are necessarily different, in accordance with the directions in which they may be running. Wind waves combined with half counter tides, always give maximum results, on account of the tide being nearly full, and also because the waves are larger and have greater power.

Ground swells with flow-tides usually cut out. They sometimes form transverse ridges, or beaches similar to those due to easterly winds, but in these cases the cutting out is generally in excess. Ground swells at the beginning of the ebb tide sometimes cut out, especially near Courtown, where the rise and fall of the tide is only a few feet. Ground swells with E. winds sometimes seem to assist in filling in the beaches, but with N. E. winds they cut out. Ground swells with the counter tides cut out the beaches. Ground swells with the half counter tides, that run east, fill in the beaches.

The cutting out due to ground swell or contrary winds is quite distinct from that due to a S. E. or any favorable wind, as the latter carries the beach along the strand from one place to another, while the former suck out the beach into deep water. Ground swells due to S. winds usually break on the shore nearly as quickly as the ordinary waves; but the ground swells due to S. W. and W. winds have intervals of one, two, five, or more minutes between them, and are much larger than the ordinary wind waves, or the tidal waves, which may be breaking at the same time, rise much higher on the beach, and often at one sweep carry away a mass of materials that it has taken a number of small waves to pile up.

Beaches may be clean swept and left empty: (1) By the tidal current alone, if for a long time there are not any contrary storm waves to stop the traveling of the beach; (2) If there are continuous winds that accelerate the traveling of a beach; or (3) If there are continuous winds that cut out the beach. In any of these cases, if the strand is left empty and a storm comes on, the marginal cliffs are left unprotected and may be rapidly denuded, a small storm having greater power when the beaches are empty than a great storm if the beaches are full, and winds which are most destructive to the beaches may have little or no effect on the marginal cliffs. The best section of a beach to preserve a marginal cliff, is one having below a slope, next above a flat or cess, higher up a second slope, and above all a second flat. Such a section is not common; full beaches more often having a slope below, and a wide flat above. The largest denudation of the coast line is north and south of Kilmichael Point.

CARRIAGE OF STONES IN DEEP WATER.

If a point a few miles from the shore in from 15 to 20 fathoms of water be chosen, and fixed by bearings, and examined regularly at low water during calms, it will be found that the stones at the bottom of the sea are always changing their position; some being carried away, while new ones are drifted on to the observed ground. On the coast of Galway, in many of the small strands, large blocks, some weighing 2 or 3 cwt., will be stranded after storms, which blocks must have traveled through water 15 or more fathoms deep. At the west end of Tacumshin Æolins sand ridge, there is below the sloping shingle beach a nearly flat sandy strand, usually free from blocks, which, on April 4, 1876, during low water, after a heavy gale from the southwest, was covered with

blocks, having deep seaweed attached, while on the slope there were other similar blocks. As the tide rose, these blocks began to drift landward, and in twenty-four hours nearly all the blocks were collected in horizontal lines. Numerous observations also proved, that blocks can be drifted in a considerable depth of water; not by the simple impulse of the currents or storm waves, but by such action combined with the buoyancy given to the stones by the growth of seaweed attached to them; and in case of small stones, it can easily be seen, during any gale, that the floatage of attached seaweed is often greater than the weight of the stones. With large stones, therefore, it would only be necessary that the stone—no matter what its size, if sufficient seaweed be attached to make it buoyant—should be loosened out of its bed of sand, to allow it to be carried and suspended in any current into which it might be drifted. In deep water the buoyant stones would be gradually and slowly drifted by the tidal currents; but after they come under the influence of the action of the storm waves their carriage would be more rapid.

ON THE HARDENING OF STEEL

By WILLIAM GALBRAITH.

From "Engineering."

At the close of last year there was a considerable amount of correspondence in your journal on the hardening of iron and steel, which was followed in the beginning of the year by the very able paper on the same subject taken as read at the Liverpool meeting of the Iron and Steel Institute, by Professor Akerman, and while it might be supposed such a paper would increase the interest on the subject the correspondence entirely ended there.

As one of your correspondents on this subject at the end of last year, I beg a little space for the consideration of one or two points in the correspondence, and in Professor Akerman's paper, which I think worthy of some attention.

I think it would be well to state first of all the facts which are known concerning the matter, at least as I stated them in my letter in *Engineering* of December 12, 1879. These are:

1. The carbon in steel is in combination both before and after hardening.
2. The per centage of carbon is neither increased nor decreased by hardening.
3. The specific gravity of steel is less after hardening than before.

The first two are, of course, "negative" facts, and it is because they are disputed that I find it necessary to mention them. With regard to the first of them, Professor Akerman draws attention to the probable existence of carbon in a third state in iron or steel, as a carbon existing in a form something between graphite and combined carbon, what he calls cement carbon.

This state of carbon, however, if it does exist, will not at all approach the diamond form, as some of your correspondents suppose, although I know it is a theory largely held in Sheffield, the reasoning of which perhaps might be obvious to some people, but it certainly does not commend itself to the scientific mind.

In all my experience in the analysis of irons and steels, I have never noticed anything to give the slightest coloring to the theory of the carbon being converted into a third form when slowly cooled from a high temperature. We certainly know that an iron or even a steel containing a large per centage of carbon, may be made to separate some of its carbon in the form of graphite if slowly cooled, and to take it up again if heated and rapidly cooled, but in all such I believe it to be distinctly graphite, or rather uncombined carbon, which separates. It is true I have sometimes noticed a block of insoluble residue when blister or cement steel is treated with nitric acid, but I have always found the residue to be slag, which is always present in the bar iron used, and hard-

ening makes no difference in the amount of this deposit or residue, and while Professor Akerman quotes M. Caron's and Herr L. Rinman's experiments in proof of the reverse, he seems painfully conscious that they are not at all conclusive, for he adds, "but until hardening and cement carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is of course still too early to say anything with certainty on this point."

If it is true that the cement carbon is left insoluble when treated with hydrochloric acid, while what he calls hardening carbon is given off with the hydrogen, I do not think there ought to be any great difficulty in determining them, as the problem would simply be a question of determining the carbon left behind, and that given off, a question which would present no great chemical difficulty.

If, however, it is a question of the "quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid" being "very different, according as the same steel was differently treated before dissolving," the difference in the amount of carbon undissolved must be out of all proportion to the difference between the hardened and unhardened steel.

For example, if a steel containing 1 per cent. of carbon leaves a residue of carbon when treated with acid equal to 2 per cent. of carbon, and on hardening leaves a residue equal to 1 per cent., it surely cannot be argued that the difference (1 per cent) should make such a complete difference in the steel as exists between it when in the hardened and unhardened state; and it must be remembered that any steel will give off a large per centage of its carbon as carburetted hydrogen on being so treated, and I may add that a varying proportion is given off according to the conditions or circumstances, *i. e.*, the temperature and strength of the acid, the size of the pieces of steel treated, &c., and if such conditions can sensibly affect the quantity of carbon left insoluble, or given off with the hydrogen, I think it is to be inferred that the molecular condition of the steel should also influence it to a considerable extent, and I will presently show that the molecular condition of the same steel when hardened or unhardened is very different. In fact, I consider Herr Rinman's and M. Caron's experiments to be rather a proof of this, than that the carbon exists in two separate forms in steel.

Another of your correspondents brings up a similar argument to Professor Akerman's, namely, that two steels of the same per centage of carbon behaved differently on treatment with nitric acid, but he omitted to say that the one was hardened and the other was not, or that the conditions of such treatment were identical.

Again, another argument which Professor Akerman advances is that if hammering or rolling makes the steel more dense, and, therefore, he argues, forces the carbon into combination, quenching the water ought to do the same; but as hardening or quenching has the very reverse effect, namely, lessens the density, the argument must fall to the ground; but I shall dwell on this point further on.

2. With regard to the second fact, namely, that there is no *loss* of carbon when hardening, Professor Akerman of course acquiesces in, but it is exceedingly difficult to remove the reverse impression, which is probably due to the loss of weight by scaling. In connection with this I quoted in my last letter some of Mr. Wrightson's experiments in proof of it, yet one of your correspondents disputed my interpretation of the experiments. Of course they speak for themselves, but my conclusion is the same as Mr. Wrightson's, for he adds, "Thus sufficiently accounting for the discrepancy between the specific gravity and the change of volume by scaling." See *Engineering*, October 10, 1879, page 284.

3. The specific gravity is less after hardening than before.

It has been a matter of the greatest surprise to me that Professor Akerman should have so completely omitted all reference to this well-known fact, more especially as I believe it is one of the most important in connection with this question, and it seems to me that an acceptance of the fact will completely upset Professor Akerman's reasoning; in fact nearly all his reasoning so based

on the assumption of the reverse being the truth.

I have taken the specific gravity of steels and irons as follows, simply for the purpose of verifying what is undoubtedly a known fact:

	Specific Gravity. Not Hardened.	Specific Gravity. Heated to 250° C. and Hardened.	Specific Gravity. Heated to 270° and Hardened.	Heated to Redness and Hardened.
Iron	7.636	..	..	7.623
"	7.504	..	..	7.471
"	7.620	7.609	..	7.605
"	7.613	7.605	..	7.603
Soft steel or ingot iron, 1 per cent. carbon	7.824	7.818	..	7.815
Cement Steel	7.627	..	7.587	7.432
"	7.588	..	7.568	7.560

These figures show conclusively the difference in specific gravity, and that the higher the steel or iron is heated the greater is the difference, and the cement steels when quenched at 270 deg. C. were *distinctly hardened.*

They also show that the difference in the specific gravity is greater in the case of steel than of puddled or ingot iron. In order that my remarks on this point might be perfectly understood:

"That first of all a *violent compression* must in such a case take place is self-evident, for we have now to do with a body heated from without, which therefore, at least when the heating has not been of all the longer duration, is apt to be warmer in the outer than in the inner layers. When now this body by dipping in a hardening fluid, or in some other way is exposed to a rapid cooling acting from without, the outer layers are cooled first, and the difference of temperature between the outer and the inner layers is greater the whole way through in the same proportion as the method of cooling is more powerful. But *the cooling is accompanied by contraction or compression*, and the more the outer layers have been cooled in proportion to the inner, with the *greater compressing* force must the former react upon the latter, which by the resistance react upon the outer layers." The italics are mine.

In support of the above, Professor Akerman uses arguments which I at least confess I do not understand, and assumes certain things to be well known facts, which I think are not quite admitted to be such; for example he says, "Burnt iron, as is well known, is the name given to an iron which through long-continued or strong heating has had the opportunity of assuming a crystalline texture, with the brittleness which accompanies it on account of the diminished cohesion of the crystals."

This letter is quite long enough already, otherwise I might dwell on this further, but I do not think Professor Akerman will defend it, nor do I think it quite admitted that "the more carbon, and in particular the more phosphorus it contains the greater is the liability of the iron to be burnt."

Let us suppose a piece of steel to be heated, and let us follow what takes place: First, then, it expands, and if allowed to cool slowly will come back to original size, minus loss by scaling. Plunge it suddenly into cold water, however, and I think the probability must be admitted that it does not get time sufficient to get back to its original state, we therefore get what he calls the *status quo* condition so far, but Professor Akerman omitted to say that this condition meant that the specific gravity was decreased, a point which I have noticed before.

But here the *status quo* condition ends, for as the steel is heated the molecular vibration increases, but this vibration is at once decreased or stopped on cooling: the molecules are suddenly arrested in their vibrating motion, and are left in a state of tension, in a condition in which they ought to have greater vibration, and the temperature too low for their distance apart.

I think the fact of the decrease of specific gravity would of itself dispose of Professor Akerman's statement that "its cooling is accompanied by contraction or compression;" but we have another fact which I think is quite as conclusive, and has a special bearing on this part of my subject.

Suppose a bar of iron or steel to be heated, and the lower part of it quenched in water. If Professor Akerman is right, it ought to be bent in such a way that

the top of it would be convex, and the bottom in the water concave; but Mr. Wrightson in his paper on "Iron and Steel at High Temperatures," read at the same meeting of the Iron and Steel Institute, shows that the very reverse is the case.

I dare say it might be asked now, "But if iron acts in the same way as steel if its specific gravity is decreased when suddenly cooled, &c., why does it not harden as steel does?" Well, it will be noticed first of all that the difference in specific gravity in the case of iron is not so great as in the case of steel, but still the difference is such that it cannot be given as the only reason, and we will find the explanation of this fact, however, and the reason why it does not harden when we consider its mechanical properties as compared with steel.

Iron is much more ductile than steel, iron can be twisted and bent in a variety of forms and steel cannot; this just means that the molecules flow with greater freedom and rapidity in the case of iron than in that of steel. So much more rapid is the molecular flow in iron as compared with steel that the molecules can nearly get back to their original position in *spite of the rapid cooling.* In fact, the amount of this decrease in specific gravity, when a metal or other substance is rapidly cooled, might be a measure of the rapidity of the molecular flow, or what is the same thing, the ductility of the metal.

There are two notable instances of this in the cases of copper and glass. In the case of copper, which is very ductile, the loss of specific gravity is exceedingly small, and in the case of glass so slow is the molecular flow that it flies to pieces when quenched, and it is only when treated in a very special manner that it can be hardened at all, *i.e.*, in the case of toughened glass, and the molecular tension is proved from its appearance with polarized light.

Altogether the relationship between ductility, decrease of specific gravity when quenched or suddenly cooled, and hardening power would be an exceedingly interesting study, and almost tempts me to make this letter even longer than it is.

ON FRICTION AT HIGH VELOCITIES.

REPORT OF THE COMMITTEE OF THE INSTITUTION OF MECHANICAL ENGINEERS.

From "Engineering."

The subject with which this Committee has to deal has been defined as "friction at high velocities, specially with reference to friction of bearings and pivots, friction of brakes," &c. As the essential question involved in this is the influence of velocity upon frictional resistance, it has appeared neither necessary nor advisable that the reporter should give any special account of what has been written upon the subject of friction generally. Unfortunately, however, the results of his examination of the numerous works and papers bearing upon the subject to which he has had access have been chiefly negative, so far as relates to the particular question in hand. Very little work appears to have been done in connection with this question; and even of what has been done much seems inapplicable—on account of difference of conditions—to the ordinary work of the mechanical engineer.

A difference has long been recognized between what has been called static friction, or the friction of rest, and dynamic friction, or the friction of motion, the coefficient in the former case being in many instances much higher than in the latter. The recent experiments of Professor Fleeming Jenkin in connection with this matter, although made at the opposite end of the scale of velocities to that about which the Committee is now chiefly concerned, have great interest in connection with the general question of velocity and friction. By experimenting at extremely low velocities, he has shown* that in certain cases, where there is a very marked dif-

* Royal Society. Proceedings, 1877, p. 93.

ference between the two coefficients mentioned, the coefficient of friction decreases gradually as the velocity increases, between speeds of 0.012 ft. and 0.6 ft. (0.0036 and 0.183) meter per minute; and his experiments indicate a probability of a continuous rather than a sudden change in the value of the coefficient between the conditions of rest and motion. In cases where there is little or no difference between the coefficient of rest and motion, no difference was found at the velocities between which he experimented. His experiments were made with a very small steel spindle of 0.1 inch ($2\frac{1}{2}$ millimeters) diameter only, resting in rectangular V notches, the pressure being constant, and due to the weight (86 lbs.=39 kg.) of a disc carried by the spindle, and revolving with it.

Professor A. S. Kimball has made a number of experiments* upon the question of velocity and friction. At common, but somewhat slow speeds, he finds the friction between pieces of pinewood to decrease rapidly as the speed increases. With a wrought-iron shaft of 1 inch (25 millimeters) diameter, working in a cast-iron bearing, well oiled, an increase of velocity of rubbing from 6 ft. to 110 ft. (1.8 to 33.5 meters) per minute caused the coefficient of friction to fall to 0.3 of its first value. The pressure in this case was about 67 lbs. per square inch. (4.7 kg. per square centimeter). Other experiments on lubricated journals at smaller pressures gave a diminution of the coefficient from 0.15 to 0.05, as the velocities increased from 1 ft. to 100 ft. (0.3 to 30 meters) per minute. At such slow speeds as from 0.59 ft. to 2.2 ft. (0.18 to 0.67 meters) per minute a similar decrease was found; while at the still lower velocities of from 0.002 ft. to 0.01 ft. (0.0006 to 0.003 meters) per minute the friction increased with the velocity.

Professor R. H. Thurston has carried out a number of experiments to determine the effect of changes, not only in velocity but also in pressure and in temperature, upon the frictional resistance in lubricated bearings.† His conclusions are that the coefficient at first decreases, but after a certain point increases with the velocity, the point of change varying with the pressure and the temperature. At a pressure, for instance, of 100 lbs. per square inch (7 kg. per square centimeter) and a temperature of 150 deg. F. (65 deg. C.), the minimum value of the coefficient is reached at a speed lying between 100 ft. and 250 ft. (30 and 75 meters) per minute; while at the same pressure, but at a much lower temperature (apparently), the value of the coefficient increases continuously from 30 ft. (9 meters) per minute, the lowest velocity tried, up to 1200 ft. (360 meters) per minute. As the general result of his work Professor Thurston has come to the conclusion that for a cool and well lubricated bearing the coefficient of friction increases with the velocity, and approximately as its fifth root, at all speeds exceeding 100 ft. (30 meters) per minute. It is much to be regretted that Professor Thurston has published no information about his very important experiments in this part of the subject, except a few tables of epitomized results. Neither the sizes of the journals tested, the number of tests made, nor any particulars as to the variation of the experiments among themselves are given, and very few details as to the way in which they were carried out. Until this information is made accessible (as it is to be hoped it will be made) it is not easy to estimate the degree of importance to be attached to these results.

The well-known experiments of Poirée and Bochet* show that between velocities of 900 ft. and 3600 ft. (270 and 1080 meters) per minute the coefficient of friction both of wheels and of shoe brakes skidding on rails diminished very much—approximately (in the former case) from 0.2 to 0.13. The surfaces were of course quite unlubricated.

The recent experiments of Captain Douglas Galton and Mr. Westinghouse, described by Captain Galton in his papers read before the Institution,† afford very valuable information as to the effect of change of velocity upon the frictional resistances between brake-blocks and wheels, and also as to the simultaneous variation of the coefficient

* *American Journal of Science*, 1876 and 1878; also Thurston's "Friction and Lubrication," p. 182, *et seq.*

† "Friction and Lubrication," page 185. American Association for Advancement of Science, August, 1878, page 61.

* Mem. de la Soc. des. Ing. Civ. 1852, page 110, &c.

† See Proceedings Inst. M.E., June and October, 1878, and April, 1879.

of friction with the intensity of pressure, or pressure per unit of area. These experiments throughout showed a very remarkable diminution of the coefficient of friction with increase of speed over the very large range of from 400 ft. to 5300 ft. (120 to 1600 meters) per minute. The nature of the appliances used, however, permitted observations to be made only for about 30 seconds consecutively; and it was found that during this time the coefficient of friction always diminished rapidly. This decrease must of course cease after some time—apparently after a very short time—and the question arises, as was suggested by the reporter in the discussion on one of Captain Galton's papers, whether the difference between the frictional resistances at different speeds would still remain when these resistances had taken up their lowest values, or would then have disappeared. So far as can be judged from plotting out Captain Galton's results* the difference would remain. From working out a number of these brake experiments, the reporter found that the coefficient of friction was sensibly less at higher than at lower pressures, and that the coefficient of friction between the wheel and the rails (where the intensity of pressure might easily be seventy or eighty times as great as on the brake-blocks) was less than a third of that between the wheels and the brakes. From Professor Thurston's experiments with journals there appears the notable result that, while this is substantially corroborated for ordinary velocities and loads, there comes always a point (varying irregularly in the different cases and with different lubricants), after which increase of pressure increases the coefficient of friction, this change being more marked in the case of the lower velocities. The particular point at which this change occurs seems also to be partly dependent on the temperature. Within ordinary limits Professor Thurston takes the friction to vary (*cœteris paribus*) inversely as the square root of the pressure per unit of area; but this conclusion is very far from representing the average results of those sets of experiments which he has selected for publication.

No very large number of answers have been received to the inquiries sent out upon this subject. Of those which have come in, the most interesting are (1) a letter from Mr. Pearce, of Cyfarthfa, and (2) a letter from General Morin. The former gives particulars of indicator tests of a rolling-mill engine running empty at different speeds, from which it appears that proportionately a much smaller power was required to drive the engine at a high than at a low speed. The experiments are not of such a nature as to allow any general conclusions to be drawn from them; but they have considerable intrinsic interest, as relating to a form of experiment easily made, and the results of which, noted in a sufficient variety of cases, would afford really valuable information. General Morin's letter is specially interesting, as coming from such a veteran worker in the subject of friction as its writer. He disclaims altogether any notion that from his original experiments laws of friction could be laid down for conditions outside those under which he worked; and sees no reason to doubt that under such high velocities as often occur in practice the coefficient of friction may be considerably reduced. He thinks that an apparatus somewhat similar to that which he used, but modified in detail, would probably be the most convenient for carrying out further experiments. General Morin's letter is appended to this report.

The chief experiments made directly in connection with the subject under the consideration of the Committee have now been cited. From them it may be taken as established that, even at quite ordinary speeds, the value of the co-efficient of friction between different varieties of iron or steel is sensibly changed by changes in the velocity of rubbing. For dry rubbing surfaces, there can be little doubt that this change is a continuous decrease as the velocity increases up to the limits of the experiments made; for lubricated surfaces, of the form of ordinary bearings (having, however, pressure on both sides of the journal), Thurston's experiments point to the conclusion that at some point the coefficient ceases to decrease with increasing velocity, and begins to increase again. This conclusion can hardly be accepted as final without confirmation.

* Proceedings Inst. M.E., April, 1879, Plate 23, Fig. 14.

It has as yet been found only by one experimenter, and his results are in many points anything but regular. But at the same time no other experiments have apparently been made with lubricated bearings at anything like the speed (1200 ft. or 360 meters per minute) up to which he has worked.

Besides the general conclusions that the coefficient of friction is greatly affected by the velocity of rubbing, the existing experiments also show that it is greatly affected by the intensity of bearing pressure; and they raise some probability that the effect of altering the pressure is different at different speeds. It will hardly be possible therefore, in carrying out any experiments which may be thought advisable upon this subject, to dissociate the question of varying pressure from that of varying velocity. In working with lubricants it is also clear that the temperature very much affects the coefficient of friction; but there is very little evidence as to the effect of ordinary changes of temperature upon dry bearings.

TRANSLATION OF A LETTER FROM GENERAL A. MORIN.

"The results furnished by my experiments as to the relations between pressure, surface, and speed, on the one hand, and sliding friction on the other, have always been regarded by myself, not as mathematical laws, but as close approximations to the truth within the limits of the data of the experiments themselves. The same holds, in my opinion, for many other laws of practical mechanics, such as those of rolling resistance, fluid resistance, &c.

"It has therefore been no surprise to me that, in experiments on the resistance to the sliding of skidded railway wheels over rails, this resistance has appeared to diminish at higher speeds. The vibrations and strains produced in such cases would moreover occasion disturbances such as would wholly change the results.

"For journals revolving in stationary bearings, it is natural that, as the efficiency of the lubrication is affected by the speed, the friction should be so also.

"In the case therefore of loads, surfaces, or speeds, which largely exceed the limits of those that have formed the subject of my own investigations, I agree with the Institution of Mechanical Engineers that it would be well for further experiments to be tried.

"But after mature consideration I am of opinion that the question might be solved by an apparatus of a kind similar to the one I made use of, as described in the paper published in 1838 by the Academy of Science; provided that the new experiments were tried on a larger scale in regard to weight, diameter, and speed.

"In the apparatus referred to, the rotary dynamometer, which was the first of its kind, was mounted direct on the axle that was being experimented upon. It would be better that it should be separate from it, and that the axle should be driven by a belt.

"The kind of rotary dynamometer that I have subsequently employed, of which there are several models in the Conservatoire, is very convenient for these experiments, and can be used for high speeds. It would afford greater facility for applying sufficiently heavy loads.

"The diameter of the bearings should be much greater than is required for strength, in order that a sufficiently high surface velocity may be obtained with a moderate speed of revolution.

"For experiments made without any lubrication, anomalous results arising from wear produced by long-continued friction of the same surfaces might be avoided, if, instead of fixed bearings, an annular bush surrounding the journal were employed, which by some easily contrived arrangement might be shifted circumferentially at pleasure, either with a continuous movement or at intervals.

"The above are the suggestions that at present occur to me to offer in regard to arranging further experiments on the friction of axles in their bearings.

"If any scheme for an experimental apparatus in accordance with these ideas be submitted to me by the Institution, I shall have much pleasure in examining it and giving my opinion upon the arrangements proposed."

ON THE DECOMPOSITION OF SOME EXPLOSIVES.

From the "English Mechanic."

A series of researches have been recently undertaken by MM. Sarran and Vieille, with a view to fixing the conditions of use of gun-cotton in mines. Through the important improvements introduced by Professor Abel into the manufacture of gun-cotton, this explosive is now prepared in homogeneous masses of determinate form and density, and can be kept without danger in the moist state. Its explosive force, comparable to that of dynamite, is greatly superior to that of powder, hence its use in mines offers great advantages. One inconvenience, however, connected with it is the production, on explosion, of noxious gases, which inconvenience the workmen. Its decomposition, in fact, produces carbonic oxide. This may be obviated by adding to gun-cotton an oxidant, such as a nitrate.

In a first communication to the Paris Academy, MM. Sarran and Vieille study comparatively the products formed, the heat liberated, the pressure developed by explosion in a closed vessel (1), of pure gun-cotton (2), of a mixture by equal parts of gun-cotton and nitrate of potash (3), of a mixture of 40 parts of gun-cotton to 60 parts of nitrate of ammonia (4), of nitro-glycerine, and (5) of ordinary blasting-powder.

We here give the results as to qualitative and quantitative composition of the gases furnished by each explosive under the normal conditions of its use. The table shows, in litres, the volume of each of the gases per kilogramme of the substance under such conditions.

Designation of substance.	CO	CO_2	H	N	O	C_2H_4	HS	Total vol. lit
Fine gun-cotton	234	234	166	107	..	..	..	741
Gun-cotton and nitrate of potash..........	"	171	"	109	45	..	..	325
Gun-cotton and nitrate of ammonia.......	"	184	"	211	6	..	..	401
Nitro-glycerine.	"	295	"	147	25	..	..	467
Ordinary blasting powder..	64	150	4	65	..	4	17	304

In a second note, the authors present the results, very different, obtained in decomposition of the same explosives, under a pressure near atmospheric pressure. These results have a theoretic interest, because they offer a remarkable example of the influence whieh the exterior conditions of reaction exert on the nature of the products.

From the practical point of view they give information as to the nature of the gases which may be expanded in mines in the cases of failure of detonation. Indeed, in most of those cases, the explosive, simply inflamed by the priming, fuses slowly under weak pressures. The authors have verified by a direct experiment, that the mode of the decomposition which is then produced in a little resistant-medium is quite assimilable to that which they realized in their apparatus.

As formerly they completed the volumetric analysis of the gases by absolute measurement of the volume occupied at temperature 0°, and at normal pressure, by the gases of a determined weight of the substance. The following table indicates (in litres) the volume of each of the gases per kilogramme of the explosive:

Designation of substance.	NO_2	CO	CO_2	H	N	C_2H_4	Total vol. lit
Pure gun-cotton...	139	237	104	45	33	7	565
Gun-cotton and nitrate of potash..	71	58	57	3	7	..	196
Gun-cotton and nitrate of ammonia	122	65	103	12	112	..	414
Nitro-glycerine....	218	162	58	7	6	6	452

It will be seen that, in this mode of decomposition, all the explosives liberate binoxide of nitrogen and carbonic oxide. It is important, then, in mining operations, to avoid failure of detonation by taking great care in arrangement of the priming.

RIVER CONSERVANCY, ILLUSTRATED BY DRAINAGE ADMINISTRATION IN HOLLAND.

By J. CLARKE HAWKSHAW, Member Inst. C. E.

From the "Journal of the Society of Arts."

THE word "Conservancy," when applied to rivers in this country, has generally hitherto been held to mean the keeping of them in a fit state for navigation. When our rivers were more used as highways, most of them had Conservancy Boards for navigation purposes. As long as such bodies prospered, our rivers were kept in far better order than they now are, not only for navigation but for other purposes. Some of these Boards have disappeared, some remain, and still retain their powers, but many are unable, for want of funds, properly to do their duties.

For this reason, and from the growth and spread of population along the river banks, new forms of conservancy have become necessary. Pollution by town refuse led to the passing of the Rivers Pollution Prevention Act, in 1876. The greater frequency of floods during late years has made it plain that conservancy for their prevention is necessary, and has given rise to the Rivers Conservancy Bill of this Session in Parliament.

Land Drainage Boards we have in plenty; each one does something, often little enough to ward off floods in its own district. But their sphere is too limited, they rarely look beyond their own narrow banks, and they will not work together. What we want to find out is, how to control and direct their work, so that, when possible, it may be made to benefit all, and also to aid it by works which no one of them could undertake.

Some advance has already been made towards the same end in other countries, and we may help ourselves in our difficulty by seeing how it has been met elsewhere.

Of all neighboring countries, Holland has the most artificial system of drainage. The very existence of the country depends on the water in and about it being kept under proper control by artificial means, and this has been the case from very early times. We might, therefore, reasonably suppose that the necessity for laws to control and provide for the management of rivers and water channels would soon have been felt in Holland, and such we find to have been the case.

Unions for drainage purposes of all lands, high and low, have existed in Holland for several centuries. Such unions are called "Waterschappen," and their oldest charters date from the 13th and 14th centuries.

In early times, the Boards of the Waterschappen were composed of the already existing corporations, and the government of the day named persons, called "Heemraden," to control and superintend the land drainage works which the corporations carried out.

Under these corporations no great progress was made until the 15th century. As the importance of the works which were undertaken increased at that time, so also the necessity then arose for a more complete organization to supervise and control them, and more important administrative unions, called "Hoogheemraadschappen," were accordingly instituted on a basis which has remained practically unchanged to the present day. A Hoogheemraadschap is a Waterschap, whose Board is composed of a "Dykgraaf," or president, and "Heemraden," or directors, with power to execute and maintain all the drainage works in which the inhabitants of their district have a common interest, with power to control all the minor works carried out by the small drainage corporations, or "Polders," and to enforce obedience on the part of private landowners and Polders to such laws as they may from time to time make.

The following powers are possessed by all the Waterschappen:

1. In cases of emergency, when floods are imminent, they may execute works,

or remove existing works, at the expense of those who should execute or remove them, but who fail to do so.

2. They may appropriate any materials which may be of use in repelling floods. The compensation to the owners to be settled afterwards.

3. They may take the earth required to make new or restore old embankments. The compensation to the owners to be settled afterwards.

4. They may levy rates to defray their expenses.

They may, moreover, by a law of 12th July, 1855, inflict a fine, not to exceed 25 florins, or imprisonment for from one to three days, for infringement of their regulations. The intervention of a judge is required, however, to legalize these punishments. They may also shut up or put out of use all the watermills, sluices, or other works by which interference with their regulations has been brought about, and this may be done at the expense of the offending owners. The Hoogheemraadschap of Rhineland is one of the most important of the large drainage districts in Holland, and I will describe its constitution in somewhat more detail, from information kindly furnished by its president, Mr. J. S. Clercq, and by Mr. J. Waldorp, the eminent Dutch engineer.

Its first charters were granted by William II., Count of Holland, in 1255, and by Count Floris V., in 1285. It extends from Amsterdam to Gouda, over an area of 262,685 acres (106,282 hectares). It is bounded on the north by the margin of the recently reclaimed Lake Y, on the west by the North Sea, and on the south and east by the Hoogheemraadschaps of Delfland and Amstelland. There is an adjoining district of Woerden, 41,992 acres (16,990 hectares) in extent, which pays a fixed contribution for certain sluicing privileges, but which forms by itself a separate Waterschap.

The administration of Rhineland consists of a combined board, composed of 16 chief or principal landowners, six members, called Hoogheemraaden, and a president, called Dykgraaf. The Dykgraaf and six Hoogheemraaden form an executive board, over which the Dykgraaf also presides, and which is assisted by a secretary, a receiver, and a civil engineer,

Besides the 16 chief landowners, there are 16 chief landowners assistant. The two together form an electoral body of 32 number, which meets once a year, to select three persons, either for Hoogheemraden or Dykgraaf. This list is submitted to the king, who chooses one of those named in it to fill the office.

No one under 23 years of age can be a member of the Board, or a member of the electoral body, and in order to be elegible for the office of Dykgraaf or Hoogheemrad, the person must be the owner of at least 62 acres (25 hectares) of land in Rhineland, and chief landowners and chief landowners assistant must own at least 50 acres (20 hectares). Relations nearer than the second degree cannot serve together.

Rhineland is divided into 16 electoral districts, each of which elects one chief landowner and one chief landowner's assistant. All persons, companies, and corporations paying yearly taxes for not less than 2½ acres (1 hectare) have a right to vote. The payment of taxes on 2½ to 12½ acres (1 to 5 hectares) gives the right to one vote, and so on up to 200 acres (80 hectares) which gives the right to the maximum number of votes, which is ten. The vote may be given by written procuration.

All the members of the combined Board, including the Dykgraaf, and also the chief landowners' assistants who serve only on the electoral Board, are elected for six years, and a certain number retire each year.

The combined Board has charge of everything connected with the constitution of the district; it decides on the regulations to be enforced, and on the measures to be taken to enforce them; it decides on the execution and manner of carrying out all new and extraordinary works; it determines the right to pump or sluice on to the general bosom or upper catchwater; it buys, sells, and leases the property of the Hoogheemraadschap; it decides when action shall be taken in the courts against those who fail to comply with its regulations; lastly, it settles all disputes between the landowners or minor polder Boards. Against its decisions in such cases appeal may be made to the Deputy States

of the province; in the case of Rhineland to the Deputy States of North and South Holland.

The executive Board, consisting of the Dykgraaf and Hoogheemraden has charge of the execution of the resolutions of the combined Board. In cases of emergency, it may act independently, and at such times it may carry out any works it thinks necessary, may make banks, occupy land, and take any materials it may require from adjoining occupiers.

The executive Board may order the removal of any obstructions which interfere with the drainage of the district, or it may remove the same at the cost of the owners if they fail to do so; it regulates all deep excavations, whether for peat or other purposes; it sees that proper precautions are taken to prevent the sand of the sandhills from blowing away; it fixes the level at which the water has to be maintained in the different catchwaters or bosoms; it controls, in fact, all works affecting the drainage of the district.

The Executive Board publishes the regulations, and sees that they are enforced, and it keeps a correct register of all the taxable lands of the district.

The Dykgraaf is charged with the execution of all the resolutions of the Executive Board, and he has control over all the officials of the Hoogheemraadschap. In cases of immediate danger, he may act independently, with the full power of the Board.

The regulations prepared by the executive Board, after being open for public inspection, for 14 days, are submitted to the combined Board, who send them, with or without modification, to the Deputy States for approval. After being approved by the Deputy States, they are published, and eight days afterwards are in force.

The yearly budget which includes the salary of the Board and its officers, the expenses of the Board, the cost of maintenance of all ordinary and extraordinary works, and all other expenses, is prepared by the Executive Board, is settled by a general meeting, and has then to be approved by the Deputy States of the province. At the same time, the tax to be paid by the landowners is settled for the following year. The tax is fixed at an equal rate per hectare (with a few exceptions, resulting from old contracts, or for reasons which will be referred to later on) and is the same, whether the lands are high lands or low lands. Uncultivated sandhills, and the water area of the bosom, and bosom canals are free from taxes. The average yearly tax paid during the last 50 years in Rhineland, has been one shilling and fourpence per acre (two florins per hectare); the maximum tax in any year was two shillings, and the minimum eightpence per acre (three florins, and one florin per hectare).

The budget, after being open for public inspection for 14 days is printed and published, and the same course is pursued with regard to the amount of receipts and expenses for the past year.

All payments are made by the Receiver (Rentmeester) and the certificates are signed by the president and one member of the Executive Board. All other documents are signed by the president and secretary.

The taxes are paid in accordance with the register, which contains a correct description of all the properties in the district. This register is open for public inspection, during a fixed period.

If Rhineland neglects to execute necessary works, the Deputy States may order the execution of them, or may undertake them themselves, and charge the cost to Rhineland; the Deputy States may also propose to the King the dismissal of the Dykgraaf or Hoogheemrads, when they are either inefficient, or when they fail to carry out the requirements of the Deputy States. In all cases the King decides between the two. Any information which the Executive Board may require from the Polders Corporations in Rhineland, must be supplied by them, and they must submit to the Board their yearly budget, and an account of their administration. They may, howover, appeal to the Deputy States against the Board's decisions.

In the years 1854–5, the Provincial States of North and South Holland settled general rules for the administration of the Polders Corporations, 230 in number, over which the Rhineland Board has general control. Each Polder has its own special rules.

Any resolution of the Hoogheemraadschap, or of the small administrations of

Rhineland, may be annulled by the Deputy States, if it is contrary to law, or if it is against the interest of Rhineland, or that of the province. The only appeal in such an event is to the king.

Such is the administration of the important district of Rhineland. Other districts throughout the country are governed in a similar manner.

It is generally thought in Holland, that the existing laws are all that is required to secure the good administration of the Waterschappen, and smaller drainage districts, or Polders, which they include. In confirmation of this opinion, I am told that disputes between the different interests in the large districts do not often happen, and the right of appeal to the Deputy States against the decisions of the different Boards is very seldom used. It is, however, thought that a law is required to regulate the relations of the large districts to one another, to the towns, and to the navigations. Yet, although the want of such a law has long been widely felt, the landed interest in the chambers, who are most interested in obtaining it, and who are, moreover, in a position to do so, have not yet ventured to move for it. The administration of the Waterschappen and Polders is so good, and all interests within them are now so well protected, that there is great reluctance to take any steps which may tend to disturb or lessen the authority of the existing Boards.

In a flat country like Holland, well defined natural drainage districts do not exist. When drainage districts are not divided by natural boundaries, the interests of those which adjoin must often be opposed, owing to their making use of common channels for the discharge of land water, or from other causes; and hence arises the necessity for a law to regulate their mutual relations. In this country, no such necessity need arise, if the boundaries of the combined drainage districts are made to coincide with the natural boundaries of the river basins, which are well defined, except in limited areas, such as are met with in the few districts of the Eastern Counties, where flat, alluvial tracts stretch across the lower courses of two or more rivers.

The whole of each natural drainage district should be under one Conservancy Board; above all, it is important that the outlet, by which the waters of the district are discharged into the sea, should be under the same control as the rest of the district. On many rivers, it will be found that the cost of the works inland will depend, to a great extent, on what can be done to improve the outlets to the sea, and, if these outlets are not, in some measure, under the control of the Conservancy Board for the river, their difficulties and expenditure may be very much increased.

If Conservancy Boards are formed for drainage purposes with only partial jurisdiction over a river, they will always be able to drain their land, though, perhaps, at a greater cost, without the co operation of those situated lower down on the course of the river. But those so placed lower down will not save their pockets by not forming part of the same conservancy district, for unless they make provision for the more rapid discharge and greater volume of flood water, which will result from the works carried out above, they must suffer, more or less. This has happened in many places already, when works have been carried out by landowners on river banks without the co-operation of, and without regard to the interests of those lower down; and the same thing may happen if the drainage area near the river mouth is not under the same control as the rest of the river basin. Many of our ports are liable to be inundated by high tides, landwater floods, and combinations of the two. If the flood waters are passed to the sea more rapidly by improvements, this liability may be increased. It is therefore most desirable that no part of each natural drainage area should be left out of the union for conservancy purposes, least of all the lower parts adjoining the sea. If all are included, the interests of all can be watched and considered, and the best results may be obtained at the least cost.

In Rhineland, all lands, high and low, are obliged to contribute, in proportion to their acreage, to the general rate raised for the purposes of the Waterschap. Generally, the amount of the rate is the same, per hectare, for all. Exceptions are occasionally made in favor of some lands—when it can be proved that no benefit whatever can be derived

by them from the works for which the rate is raised. In such cases the tax is not wholly remitted; the lands are taxed at a lower rate. The principle that all lands, high and low, should contribute, is, I think, fair and right, but it may appear unjust that the rate should ever be of the same amount for the two descriptions of land. It must, however, be borne in mind that in Holland lowlands bear a very much larger proportion to the total land than in this country.

For example, the total area which drains into the general bosom of Rhineland is 302,600 acres (122,450 hectares). Of this, 26,740 acres (10,821 hectares) only, that is, less than one-eleventh of the whole consists of high land. This lies wholly within the district of the sandhills along the coast.

Of the remaining area 35,689 acres (14,442 hectares) are bosom lands. These are also held to be highlands in Holland, but they would not be called so in this country, as their average level is ten inches (.25 metres) below the mean level of the sea. The polders or lowlands in Rhineland lying from $3\frac{1}{4}$ to 5 feet (1 to 4 metres) below mean sea level, are 231,170 acres (93,546 hectares) in extent, and, lastly, the area of the bosom canals and lakes is about 9,000 acres (3641 hectares).

The bosom lands serve a special purpose in Holland. The water is pumped from the polders or lowlands into the bosom canals which run through the bosom lands, and it passes by them through sluices to the rivers or the sea. The bosom lands are liable to be flooded at times, indeed they form an additional reservoir space, to supplement that afforded by the bosom canals and lakes. The bosom lands, together with the bosom canals and lakes, form the general bosom of a district. Flooding of any part of the Polders is of the rarest occurrence. The pumps on which they are dependent are never stopped until the water rises to such a height on the bosom lands as to endanger the banks which divide them from the Polders. If the banks were to give way, all the water stored on the bosom lands would inundate the Polders. Rather than risk such a serious flood, the pumps would be stopped, and the rainfall would be allowed to accumulate on the lowlands for a time.

In the Fen districts of this country much of the land, corresponding to the bosom land of Holland, has been separated from the general bosom, and the receptacle for flood water has been thereby diminished. Such misappropriations are still going on, and, though a few landowners gain for a time by them, they, as well as their low-lying neighbors, must suffer in the end. The so-called dales along the River Witham were bosom lands; they now form part of the Fens, though the old banks which separated the two in former times still remain in places. In Holland, no such conversion of the bosom land into Polder land would have been permitted. That the area now left for bosom water is wholly insufficient in the Witham district, was shown by the disastrous floods which happened in 1877. In this country there is no Board, as in Holland, with power to say when it is no longer safe to pump water from the fens on to the bosom. Each fen continues to pump, quite regardless of the height of the bosom water, which may often be running back over the banks to its own pumps. The banks must give way sooner or later, but each fen hopes that its own bank may not be the first to fail. The failure of a bank may cause one or more fens to be submerged to a depth of five or six feet, whereas a few hours' cessation of the pumping throughout the district, might often prevent such a disaster. In Rhineland, by stopping the pumps which drain the Polders, a serious flood may always be prevented; but it would not always be so in this country, for we have to contend with an immense volume of highland water, which is not the case in Rhineland.

It is now an accepted fact that the water from much of the highlands is discharged more rapidly into the rivers than it used to be. An owner of the high land may say, "I bought my land subject to no charge for a river conservancy rate;" but with equal truth the owner of low land may reply, that when he bought his land it was not liable to be overflowed by the large volume of water which the owners of the high lands now pour into the river by their improved system of drainage. But

apart from such arguments, which are only of partial application, the principle that all lands should pay to maintain the main channels which, directly or indirectly, drain them is surely a fair one. If the incidence of rates is only to be determined by the benefits received, very many could not be justified.

No doubt the lowlands will benefit most, as now they suffer most, and they should bear the largest burden of the cost, the more so as they have to some extent rendered themselves more liable to be flooded, and have in many cases made the works which will be required to prevent floods more difficult to design, and more costly to execute.

In the first instance, costly works will often be required; works designed only to meet local requirements will have to be done over again, or be done away with altogether; obstructions will have to be removed which have grown up in the river channels, from natural causes, during years of neglect, or which may have been placed there to benefit individuals.

But even for such works no such rate need be feared as the land in Holland is subject to. Holland has to provide an artificial drainage for nearly all the land; we have, in most cases, only to provide that a good natural drainage system is kept in order, for, fortunately, the land in this country, which is without a good natural drainage, is very small in extent, when compared with the whole area.

To make a satisfactory law which shall provide for the government by one body of such large districts as are drained by our rivers, is a task of extreme difficulty To put it in practice will be more difficult. The interests which have to be dealt with are so many and so great that it will be impossible to satisfy all. In Holland, where want of such a general law is more keenly felt than here, they have not ventured yet to prepare it. Still, they are far before us in river conservancy. They have large districts admirably administered, and under the charge of able drainage engineers, and they, moreover, have recognized the principle that all land should contribute to maintain the channels which convey the water flowing from it into the sea.

THE PRESERVATION OF IRON FROM OXIDATION.

From "Iron."

It is now about three years since Professor Barff announced to the world his happy idea of applying in practice the well-known principle of exposing heated iron to the action of superheated steam, whereby it acquires a tenaciously adherent coating of magnetic oxide, which acts as a preservative of the metal against rust. We have now to announce the practical perfecting of another process for producing the same results which has been developed by Mr. George Bower, of St. Neots, Hunts. This consists in exposing heated iron to the action of air, and also of carbonic acid, whereby it not only acquires an equally efficient protective coating of the magnetic oxide, but at the same time assumes a delicate French-gray color, which for many purposes obviates the necessity for painting the metal. Before describing this process, it may prove interesting if we briefly glance at the history of its development. And first we may observe that it was only by the merest chance that Mr. Bower did not discover the very process which has added so much to the fame of Professor Barff. It appears that some twelve or fourteen years ago, Mr. Bower was making some experiments connected with the decomposition of water, by passing steam through red-hot iron in a retort, when he found that the iron decomposed the water rapidly at first, but that it gradually got less and less active, until it ceased to have any effect whatever. This led him to make an examination of the iron, when he found it coated with a sort of enamel, which suggested the idea of the process being used for that pur pose. Upon exposing it to the atmosphere, however, the coating separated from the body of the iron, and Mr. Bower pursued the matter no farther. This separation was due, no doubt, to the iron operated upon being old and rusty. If it had been new the proba-

bility is that Mr. Bower and not Professor Barff would have been the first to introduce the coating of iron by magnetic oxide, produced by the action of aqueous vapor on red-hot iron.

When Professor Barff's success was published to the world it occurred to Mr. Bower that what the Professor was able to do with water he could do with air, and he began a series of experiments which, by dint of patience and perseverance, and the expenditure of a considerable amount of time and money, ended in complete success. The air-process, thus perfected by Mr. Bower, consists in the use of a retort or chamber, heated by the external application of heat. In this chamber the articles to be treated are placed, and when red hot, a few cubic feet of ordinary air are blown into the chamber, and the cover is tightly closed and left for a short time, when it is found that the iron has entered into combination with the oxygen in the air, and a first thin film of magnetic oxide has been formed. By repeating the operation as many times as may be necessary (and this depends on the nature of the articles operated upon) the desired thickness of the coating is produced. The time required for producing the protective coating varies from six to ten hours. Beautiful and simple as this operation is, it was found in practice that it was attended with considerable difficulty, and great wear and tear in heating the chamber and the articles in it by the external application of heat. It, however, occurred to Mr. Anthony S. Bower, a son of Mr. Bower, that it would be a great step in advance if the articles could be heated by the combustion of gaseous fuel inside the chamber, and if the coating of magnetic oxide could be produced at the same time. Thereupon commenced another long series of experiments, during which hundreds of tons of castings were treated and broken up as failures, but only to end, as in the purely air process, in complete success. Having recently been afforded the opportunity of investigating the working of this improved process at Mr. Bower's works, we are able to place all particulars before our readers.

In carrying out the process a set of three small gas furnaces for the production of carbonic oxide are constructed by the side of a chamber sufficiently capacious to contain about a ton of miscellaneous articles, and which, when we were examining the process, consisted of gas brackets and lantern frames, umbrella-stands, pots and pans, and ornamental figures and panels. Under this chamber is a series of pipes for heating the air, by the spare heat as it escapes from the furnace to the chimney, prior to its being used for the combustion of the carbonic oxide. This improved process, the joint patent of father and son, consists in alternately oxidizing and deoxidizing the iron. The articles are heated by burning the gaseous fuel inside the closed chamber, and heated air—in excess of the quantity necessary for the perfect combustion of the gas—is made to enter along with the fuel. This air together with the product of combustion (carbonic-acid gas) produces, next the metal, magnetic oxide, and on the top of it a film of sesquioxide, which is reduced to magnetic oxide by shutting off the air and applying carbonic oxide only, for a short time. But this is not all, for in addition to the protection from rust, the articles are rendered ornamental in appearance by the delicate French gray of the outer film of the coating they have received. If, however, the color should not be suitable from an artistic point of view, there is the certainty, that if it be necessary to paint over the coating, it will stand the same as if painted on wood or stone, as no rust can form underneath to throw the paint off, as is the case with paint upon ordinary iron. Another great feature of the process is, that it is an inexpensive one. The apparatus we saw at work at St. Neots is capable of dealing with a ton of ironwork per day, and the wages of one laborer and the cost of five or six cwts. of small coal is all the expense attending the operation.

Where there are foundries connected with blast-furnaces the process may be carried on at very little expense as pipes, and such-like goods could be oxidized by the hot-air blast, and, if necessary, be deoxidized by the furnace gas. Indeed, one of the best samples of iron Mr. Bower now has, is a bar which was subjected to the action of the hot blast by Messrs. Cochrane, of Dudley, so long ago as the middle of 1877, and it as perfect as ever, though it has been exposed out of doors ever since that time. In the Birmingham

and Wolverhampton districts there are thousands of tons of small castings produced daily to which the process could be applied. Indeed, the process opens out a new field altogether for the application of iron to the arts, and renders it capable of taking the place of some of the more expensive metals. The oxide thus formed has been tested very thoroughly, and is found to withstand all ordinary atmospheric conditions perfectly. It appears to be thoroughly incorporated with the metal, as, indeed, it must be, for it is the union of the iron with oxygen which forms the coating. A firm of iron-founders in Glasgow have successfully put the process to a severe proof both by fire and water, while Mr. F. J. Evans, the late engineer of the Chartered Gas Company, and Mr. Joseph Kincaid, C.E., both approve of the process after having tested for a lengthened period articles coated by it, and we can testify to its simplicity and the beautiful results obtained by it. We may also add that we have tested articles protected by this process by exposing them to the weather during the whole of last autumn and winter with the most satisfactory results. We certainly congratulate Mr. Bower and his son upon their double success in rendering cast and wrought iron not only useful but ornamental.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The July No. of Transactions contains the following papers:

No. 196. The Hudson River Tunnel, by Arthur Spielman and Chas. B. Brush.
" 197. American Natural Cement, by F. O. Norton.
" 198. Notes on the South Pass Jetties, by Max E. Schmidt.

Wood Preservation.—To Engineers, Architects, Preservers of Wood, Chemists and others:—

The undersigned, a Committee of the American Society of Civil Engineers appointed to report upon the Preservation of Timber, earnestly solicit information concerning past experience in the impregnation and preservation of that material. Particulars of failures in this country, and if possible the reasons therefor are especially desired. Also, information on the following points, in each of the processes, which may have been used:

1. Kind of timber operated on—green or dry, age, dimensions, etc.
2. Preserving ingredients injected.
3. Quantity injected per cubic foot or tie.

4. Mode of application, process, time employed, degree of heat, pressure, vacuum, etc.
5. Subsequent use and exposure of timber, (bridges, buildings or track.)
6. Result of preparation and comparison with life of unprepared timber.

This special and any general information on the subject is respectfully solicited.

Replies can be mailed to the Chairman of the Committee, B. M. Harrod, *Chairman*,
122 Common st., New Orleans, La.
G. Bouscaren, 82 West 3d st., Cincinnati, O.
E. R. Andrews, 10 Warren st. New York City, N. Y.
E. W. Bowditch, 60 Devonshire st., Boston, Mass.
Col. Geo. H. Mendell, U. S. Engineers, San Francisco, Cal.
J. W. Putnam, P. O. Box 2734, New Orleans.
Committee.

Engineers' Club of Philadelphia.—No. 5 of the Proceedings which has just come to hand contains:—

No. XXI. Angular Pitch of Square-threaded Screws, by Wilfred Lewis.
No. XXII. Water Gas from Coal and Petroleum, by Gen. H. Haupt.
No. XXIII. The St. Gothard Railroad, by Chas. E. Billin.

IRON AND STEEL NOTES.

Northern crude iron trade.—The condition of the crude iron trade of the North cannot be considered an entirely satisfactory one; but the most remarkable feature about it is the extremely irregular state of prices, both of iron and of the raw materials. It is true that as contracts expire this is being remedied; but it is tolerably certain that at the present time there is such a variance in the prices that are being received by the makers for pig iron as is rarely known. Some contracts are now expiring for crude iron at 3*l.* per ton, or over 1*l* 3s. above the market rate, but they are accompanied by a very high cost of production in a few instances. The rapid fall in the price of pig iron and also in that of coke caused this irregularity, and as contracts are being renewed on a lower level it is being reduced, whilst the slight tendency of prices upward is also assisting in the renewal. But it cannot be denied that the fall in the demand for crude iron for the United States has already registered its full effect on the prices, though it is possible that it may be in the future known through diminished production also. As the price of pig iron advanced in the North of England under the influence of that inflation of demand known at the end of last year, there was a rapid rise both in prices and in the extent of the output of crude iron; and had it not been for the increased requirements of the local shipbuilding trades, the fall in prices within the last two months would have been before this followed by a decline in the extent of the production also. But the large demand for plates and angles has caused stocks of pig iron in the hands of makers to decline, and up to the present it may be said that there

is a demand up to the production, so that a restriction of the output from this cause is not yet probable. It may, however, follow from another cause.

A large number of the furnaces in the North of England, and especially in the Middlesbrough district, may make iron to profit even at the present low range of prices. Some of the owners of these own also the coal mines that supply fuel, iron mines, and limestone quarries for the flux, so that there is only the addition to cost of a percentage to the wages of the ironstone workmen and furnacemen, and of the addition to the cost of carriage made at the beginning of the present year. But many of the furnaces are not worked under these conditions. And where the owners do not own the contributory mines, and where the furnaces are situated at a distance from the latter, or from the sea coast, they cannot be expected to produce iron so cheaply as those more favorably situated. It is to be expected that if the present range of prices long prevail there will be a reduction in the output by the blowing out of some of the more isolated furnaces. If, however, a renewed demand for pig iron were to set in from the United States or from any other quarter, with the present balance between the demand and the supply, an increase in prices would be probable, which would force up prices till they were generally profitable. During the first five months of the present year, the total production of pig iron in the Cleveland and Durham district was in round numbers 1,000,000 tons—an unparalleled output—and as that was attained not only with no increase in the stocks, but with an extensive fall therein, it is certain that any present addition to the demand would force up prices. It is true that there is a reserve of productive facilities yet uncalled into action —to the extent of about forty blast furnaces in the whole of the northern district; but a large number of these furnaces are so placed that it is impossible to light them up early. Companies owning one-half of these furnaces are in liquidation, and their works could not be started for many months. With the low level of prices now attained, then, any fall in demand would be reflected by a declension in the output; and any increase in the demand would most probably be early followed by a rise in the prices. In this fact, then, there is the key to the future condition of the crude iron trade of Cleveland and Durham, if it be concurrently remembered that there is a larger production of hematite iron, and thus a larger consumption locally—a larger consumption, that is, in the locality of the quality of iron of all kinds produced in the district. It is very doubtful whether the tide will turn in the one direction or the other; but it seems to be most probable that there will now be an addition to the demand from the United States, though probably on a much more limited scale than that which has now been almost entirely gratified. It seems to be clear that English iron can, despite the heavy duty, be landed in the United States cheaper than the native metal can be produced; and whilst this is the case it is almost certain that there will be a continuance of shipments from this country When the great bulk of the iron that has recently been sent to America was contracted for, the prices here were at a very low ebb, and as prices rose new orders became less, though in fulfillment of these old orders there was an increasing shipment. Now that what may be considered the lowest range of prices are again reached, there are renewed inquiries from the United States both in Cleveland and in Scotland, and these are tolerably certain to result in new contracts. It may be taken, then, as the most probable future course of the trade, that a slow upward movement will set in. Slow, because the facilities of production in use in the North of England and in Scotland are very much greater now than they were when the demand previously set in; and this being so, and the supply having hitherto allowed of very large shipments to the United States, these large shipments may still be made without derangement of the balance between supply and demand that is supposed at the present to exist. Should this prove to be the case, the fall in the stocks that has been known in the Cleveland district during the greater part of the year may be expected to continue, and with that fall there would be the movement upwards in price which we have indicated as probable. A short time will show the movement of the tide, but its speed will not be so great as on the last setting in of the flow.

The Iron Production of the United Kingdom.—Mr. W. G. Fossick, of 86 Cannon street, has recently prepared and published, through Messrs. E. and F. N. Spon, of Charing Cross, a very complete and carefully compiled statistical diagram of the iron and steel trades of the United Kingdom from 1830 to 1880. This diagram shows, for the last fifty years, the total production of pig iron, the exports of iron and steel, and the stocks of pig iron in tons at the end of each year. It also includes, for the same periods, the prices of Scotch pig, Welsh bars, Staffordshire bars, and iron rails between 1864–1880, and steel rails from 1864 to the present time. Information is thus given at a glance, which it would be tedious to obtain from statistics, and in a manner to show strikingly the variations in the trades dealt with for half a century. As may be expected the gradations in production, though always increasing, show periods of deep depression. The following figures taken from this diagram are of interest:

Year.	Production of Pig Iron.	Price of Scotch Pig.	Price of Welsh Bars.	Price of Staffordshire Bars.
	tons.	s.	s.	s.
1830	678,417	102	110	117
1834	158,166	86	115	135
1840	1,396,400	77	135	158
1852	2,701,000	37	92.5	120
1853	1,261,272	65	190	220
1872	6,741,920	70	140	160
1879	6,200,000	40	93	150

The above are the lowest prices of the respective years, and in some cases were subject to remarkable fluctuation. Thus in 1872, when the lowest prices for Scotch pig and Welsh and

Staffordshire bars were respectively 70s., 140s., and 160s., they touched 130s., 290s, and 320s. respectively, to suffer, however, a very severe fall again before the close of the year. Steel rails were at their highest prices—17*l.* 10s.—in 1864 and 1872–73, to fall, however, in 1870 to 10*l.*, and last year to 4*l.* 10s. The year 1873 was another prosperous season for iron rails, which touched 12*l.* a ton, and last year was the worst, as they fell to nearly 80s. We strongly recommend this chart to every one interested in the British iron trade, and we may add that it is extremely well executed.

RAILWAY NOTES.

TRACTION ON TRAMWAYS.—The Paris Compagnie des Omnibus have been carrying out on one of their lines an interesting series of dynamometric experiments to determine the relative resistance of tramway vehicles and omnibuses running on the ordinary road. The line on which the experiments were made is that between the Eastern Railway Station and Montrouge, and the results have been lately communicated by M. Rousselle to the Société d'Encouragement pour l'Industrie Nationale. From M. Rousselle's paper we learn that the total length of the line between the terminus of the Eastern Railway and Montrouge in 3.95 miles, of which about 1.84 miles are fairly level. Leaving the Eastern Railway Station, there is first a sharp descent of 1 in 48 for about 480 yards, then a tolerably level length of about 1¼ miles, and then a steady rise to Montrouge, commencing with a steep gradient of 1 m. 35.7 for a distance of about 530 yards. From the top of this last-mentioned gradient the rise becomes gradually less severe for the last 530 yards or so before arriving at Montrouge, having a gradient of 1 in 666 only. The runs were made over the line in both directions, an extra horse being attached during the ascent of the steep gradient of 1 in 35.7 above mentioned, and the journey was made from the Eastern Railway Station to Montrouge in 51 minutes, while that in the reverse direction was made in 44 minutes. The speeds were the same for both omnibus and tramcar. The omnibus used weighed loaded 3 tons 12 cwt., and the tramcar 6 tons, while the dynamometer employed enabled a record to be obtained of the work done on each portion of the course. The general results were as follows: In the trial with the ordinary omnibus the work done by each horse on the journey from Montrouge to the Eastern Railway Station varied from 54,196 to 29,010 foot-pounds per minute, the mean for the whole trip being 36,892 foot-pounds per minute. On the reverse journey the work done per horse varied from 60,097 to 21,934 foot-pounds per minute, the mean effort for the run being 34,901 foot pounds per minute. The mean of means for the two journeys is thus 35,896 foot-pounds per minute exerted by each horse. In the case of the tramcar, on the other hand, the work done by each horse on the journey from Montrouge to the Eastern Railway Station varied from 36,403 to as little as 4392 foot-pounds per minute, the mean for the whole run being 23,834 foot-pounds per minute. On the reverse trip, on the other hand, the work done per horse varied 52,798 to 18,123 foot-pounds per minute, the mean for the journey being 32,348 foot-pounds. The mean of means for the tramcar is thus a power exerted of 28,091 foot-pounds per minute for each horse. This is considerably lower than in the case of the omnibus, but, on the other hand, as M. Rousselle points out the exertion in starting is far greater in the case of the tramcar than in that of the omnibus, and this involves increased fatigue for the horses. The pull exerted at starting was found to vary from 440 lbs. to 772 lb.s in the case of the omnibus, and from 617 lbs. to 1100 lbs. in the case of the tramcar. As for the resistance to traction per ton, it was found, taking the means of the journeys in the two directions (so as to eliminate the effects of gradients as far as possible) to average 42 lbs. per ton for the omnibus, and 20.1 lbs. per ton for the tramcar; the mean pull exerted by the horses thus being $42 \times 3.6 =$ 151.2 lbs. in the case of the omnibus, and 20.1 $\times 6 = 120.6$ lbs. in that of the tramcar.

HUGHES'S STEAM TRAMWAY LOCOMOTIVE.—Hughes's patent tramway locomotive, which has already been adopted in Glasgow, Wantage, Paris and Lille, made a trial journey through the streets of Birmingham, on Friday last, with the Mayor and several members of the Corporation. The locomotive resembles externally a small tramcar on a level. It draws three cars, each drawing forty persons, and is calculated to draw a car of forty passengers up a gradient of 1 in 13. It has 9-inch cylinders, 12-inch stroke, and 3-feet 6-inch cells, fitted with condensing apparatus, and runs five miles with one supply of water and coke. The trial was deemed satisfactory.

ENGINEERING STRUCTURES.

RECONSTRUCTION OF THE TAY BRIDGE. Readers of *The Engineer* are aware that by favor of Parliament the standing orders were suspended, so that a Bill has been introduced this session for the re-building of the Tay Bridge. Power is taken in the bill to raise £2 0,000 additional capital, either in the shape of ordinary or preference stock, with borrowing powers to an equal amount; and as the North British Company is at present losing much money in conducting its traffic without the bridge, the works will be entered upon and pushed forward with all possible expedition. The plans for the reconstruction of the bridge have been lodged in the Dundee Sheriff Court. When the bridge was originally constructed, after a public inquiry, it was stipulated that there should be a clear height below the central girders above high-water mark, so as to keep the water way clear for ships passing up the river to Perth. Such a requirement was considered by many unnecessary for all the traffic ever likely to find its way beneath the bridge, and the alteration in the mode of loading the central girders, which this stipulation rendered essential, appears to have been tacitly allowed to have had the effect of diminishing the stability of the structure at this point. It is therefore believed that no serious opposition

will be offered in parliament to the lowering of the height of the bridge, which is proposed to be done in the center from 88 feet to 57 feet. According to the plans, it is proposed to begin to lower the line on the Fife side, in the parish of Forgan, some distance before it reaches the structure, by a gently falling gradient, until it joins the south end of the bridge, when the height will be 57 feet. This height will be continued from the south end until the eighth fallen pier is reached, when the line will begin to fall gradually towards the north shore. For a considerable distance on the Fife side the line falls at a gradient of 1 in 300 until it reaches the bridge, when there is a slight rising inclination for 600 feet. From this point the line is almost level until the eighth fallen pier, where the fall in the line begins at 1 in 230, and gradually increases till, near the north of Dundee side, it is 1 in 74. The spans in the southernmost portion of the bridge still remaining are not to be altered in width, but the 13 wide spans of 245 feet, which were in the center of the bridge before the accident, are to be narrowed to about one-half the width by the introduction of additional piers. The first five 245-feet spans, counting from the south end of the fallen portion, are to be divided into ten spans of 109 feet each, and will stand at a height of 57 feet above high water of ordinary spring tides; between the fifth and sixth fallen piers there will be two spans of 100 feet wide and 57 feet in height; between the sixth and eighth fallen piers four spans of 109 feet wide and 57 feet high; between the eighth and ninth fallen piers two spans of 100 feet wide, gradually falling in height from 57 feet to 54 feet 9 inches; and from the ninth fallen pier to the first remaining pier on the north side there will be eight spans 109 feet wide, and falling in height from 54 feet 9 inches to 45 feet. The width of the other standing spans of the bridge is not to be altered, but their height will be modified to suit the falling gradient of the line; and the bowstring girder close to the Dundee shore will, in accordance with this provision, be reduced to 26 feet, and the smaller girder that spans the esplanade, before the station is reached will be lowered to about 18 feet. The line will be carried across the entire way on the top of the girders, so that the expedient resorted to by the engineer in the fallen portion of sending the train through the center of the girder will not be repeated. In the meantime it is not proposed to construct the bridge so as to admit of a double line of rails; but the new piers will be of such width that they will be able to carry a double line, should such a thing be resolved upon at a future time. Of course the plans are subject to such changes as may be required by the Board of trade. By a clause in the bill the Company ask for power to delay the traffic on the bridge, should that be deemed necessary, on account of the state of the weather.—*The Engineer.*

A *Times* correspondent at Bucharest writes that Sir Charles Hartley has been making his annual inspection of the Sulina and the works of the European Danube Commission. The works advocated in his report for this year comprise the cutting of a new entrance, 3000 feet long, into the Sulina branch from the main St. George Channel, in order to avoid several very ugly bends at the present entrance, which are not only very troublesome for long steamers as well as sailing vessels, but which are constantly growing more shallow from the sediment deposited on the dead angles of these bends; also the deepening of the mile reach of Gondarva, where there is only a depth of 13 feet at low water, whereas the average depth of the rest of the Sulina branch is over 15 feet at low water. To execute this latter work, Sir Charles advises the purchase of a new dredging machine at a cost of 370,000 francs. For the remaining two years of the duration of the Commission the eminent engineer advises the cutting of two other canals, each 3000 feet long, to get rid of two more very objectionable bends. The total expenditure of these improvements, including the cost of the dredge, is a little over 3,000,000 francs. When the above-mentioned improvements are completed, the Sulina branch will have a depth of 15 feet at low water, the objectionable bends will have been obviated, and the navigability of the channel reduced to a uniformity throughout its entire length, which cannot be improved without extensive works along nearly the whole of the distance, and costing a very large sum of money.

ORDNANCE AND NAVAL.

An Enormous Steamer.—John Elder and Co., Glasgow, are to build for the Guion Line a steamer 500 feet long, 50 feet broad, and 40 feet deep; engines 10,000 horse-power; indicated and gross tonnage 6400.

Large Orders for Torpedo Boats.—Large orders for torpedo boats are now being executed by Messrs. Thorneycroft, of London. The firm has delivered eleven first-class and twelve second class torpedo boats. Four are now awaiting official trials, six are shortly expected at Portsmouth, and there are being built another first-class and twenty additional second-class boats. A first-class boat costs over £5000, and a second-class half that amount. Other torpedo boats are also being supplied by other firms.

The "Albert Victor."—On the 3rd of July, this ship, taken by Mr. Samuda, her builder, and Messrs J. and W. Penn, the makers of her engines, from Gravesend to Folkstone, where she at once began her career as one of the South-Eastern Company's passenger boats across the Channel to Boulogne. The Albert Victor, steaming against a strong head wind took only three hours and 45 minutes on the run from Gravesend to Folkstone, a distance of 84 miles, her prodigious speed, steadiness, and freedom from vibration, exciting the special admiration of Mr. E. J. Reed, M. P., who, with Mr. Norwood, M. P., several directors and officials of the South-Eastern Railway, and a party of friends, had been invited to take part in the trip. At the luncheon, Mr. Samuda

stated that the Albert Victor, steel-built and with oscillating engines developing 2800 indicated horse-power, accomplished 18½ knots, and was about the fastest thing afloat. Mr. Penn also made some striking remarks about the engines, which were not compounded, and therefore not the most economical of coal, but which for driving power and results in speed put to the very best possible use the saving in weight and the improvement in her lines obtained by the use of steel in the fabric of the ship. This saving in the case of the Albert Victor is about 130 tons.

LAY TORPEDOES.—The manufacture of Lay torpedoes is being carried on with great energy in Russia, and several of these formid able weapons will, it is stated, be shortly completed and forwarded to the chief ports on the Baltic and Black Sea. The Lay, like the Whitehead, is a locomotive torpedo; but while the latter, after it is once launched, is no longer under control, the movements of the former can be guided and directed throughout its course. At the will of an operator on shore, or on board a ship if the torpedo is discharged from the latter, it can be made to turn to the right or left, to rise or sink in the water, to explode at any moment, or finally, should it fail to reach the object against which it is sent, it can be brought back again to the point from which it started. A few months ago some very successful experiments were carried out with Lay torpedoes in the Scheldt, near Antwerp, when one of them was sent against a boat anchored 3000 meters, or very nearly two miles from the operator on the bank of the river. To reach its mark the torpedo had in the first instance to move along a line of buoys at an oblique angle to the current, and had then to turn on to a course at right angles to the direction it had been previously taking; and this difficult feat it successfully accomplished. That a torpedo which can be thus kept under control up to the moment when it becomes desirable to explode it must prove extremely valuable for coast defence purposes is very obvious; and therefore it may be assumed that it will soon be adopted by other countries besides Russia.—*Iron.*

BOOK NOTICES.

PUBLICATIONS RECEIVED.

A MANUAL of the Alkali Trade, including the Manufacture of Sulphuric Acid, Sulphate of Soda and Bleaching Powder. With 232 illustrations and working drawings. By F. Lomas. Longmans, Green & Co. Price, $20.

Bulletin of the American Geographical Society No. 4. Printed for the Society.

Proceedings of the Institution of Civil Engineers:

"The Caledonian Railway Viaduct over the River Clyde at Glasgow." By Benjamin Hall Blyth, M. I. C. E. "The Purification of Gas." By Harry Edward Jones, M. I. C. E. "The Calder Viaduct." By David Monroe Westland, M. I. C. E. "Note on the San Francisco River; Brazil." By W. Milnor Roberts, M. I. C. E. "Cleopatra's Needle." By Benjamin Baker, M. I. C. E.

INSTRUCTIONS FOR TESTING TELEGRAPH LINES, AND THE TECHNICAL ARRANGEMENT OF OFFICES. By LOUIS SCHWENDLER. Vol. 2. London: Trübner & Co. For sale by D. Van Nostrand. Price, $4.00.

The present volume is especially intended to supply *testing information* to officers in charge of telegraph stations for whom the more complete testing apparatus is not available, but who have to perform their testing duties by aid of the tangent galvanometer described in the beginning of the present volume.

The present work bears no great likeness to other works on telegraphy, simply because its sole object was to introduce a general system of testing.

The Appendices treat more fully upon the theory of The Tangent Galvanometer—The Galvanic Element—Electric Resistance of the Earth, etc., etc.

QUALITATIVE CHEMICAL ANALYSIS. By SILAS H. DOUGLAS, M.A., M.D., AND ALBERT B. PRESCOTT, M.D., F.C.S. Third edition, wholly revised, with a study of oxidation and reduction. By OTIS COE JOHNSON, A.M. New York: D. Van Nostrand. Price, $3.50.

The present edition is one of the most complete of the many guides to practical chemistry. The reputation earned by the first edition has extended the use of the work among practical chemists and students throughout the country.

The additional matter which constitutes Part IV of this edition is presented, say the authors, "with much interest as to the reception which its distinctive method may obtain among chemists." This method consists in assigning a positive or negative character to the *bond.* Thus hydrogen in combination has always one bond, and it is always positive. Oxygen has two bonds always negative. The sum of the bonds of any compound are equal to zero.

Oxidizing agents are those that *increase* the number of bonds of some other substance. Reducing agents *diminish* them.

From these principles are derived rules for correctly writing chemical equations. Examples are also given for practice. The principle assumed seems worthy the serious consideration of teachers.

THE WAR-SHIPS AND NAVIES OF THE WORLD, Containing a Complete and Concise Description of the Construction, Motive Power, and Armaments of Modern War-ships of all the Navies of the World, Naval Artillery, Marine Engines, Boilers, Torpedoes, and Torpedo Boats, with 64 Full-page Illustrations. By CHIEF ENGINEER J. W. KING, U. S. NAVY. Boston: A. Williams & Co. Price, $7.00.

This work contains correct descriptions of all the modern war-ships built and building, with dimensions and particulars, and accompanied with effective drawings, showing the design, proportions, and plan of the ships, and the disposition of their batteries. An interesting comparison is made between the fighting powers of the British and French navies. The powers and dimensions of the great guns now in use or in process of manufacture are exhibited by drawings and descriptions. There

are additional chapters upon marine engines and boilers, torpedoes, and the methods of torpedo warfare, with drawings and descriptions of the latest torpedo boats.

The writer has enjoyed exceptional facilities for obtaining the information contained in the book, by personal inspection in most cases, supplemented by friendly relations and correspondence with constructors, manufacturers, and others.

The work is one that should find a place in public and social libraries, in clubs, in government offices, and one which no naval officer, desiring to be informed of the effective force of the different navies of the world, and the great changes which are being made in naval warfare, can afford to be without. It will be found useful and entertaining to the general reader also, and will be valuable as a reference book in the private library. It is especially designed to awaken the American public to a sense of the relative decline of our own navy, and inspire an enthusiastic interest in its restoration.

ARTIFICIAL MANURES; THEIR CHEMICAL SELECTION AND SCIENTIFIC APPLICATION TO AGRICULTURE. By M. GEORGES VILLE, translated and edited by WM. CROOKES, F. R. S. London: Longmans, Green & Co. For sale by D. Van Nostrand. Price, $7.50.

A book for the scientific agriculturist. The eminence of both author and English Editor is sufficient guaranty of soundness in the scientific principles. The whole is presented in a series of lectures, of which six relate to "Theory and Practice" and nine more to "Practice Extended by Theory." Separately they treat as follows:

I. Plants, their Composition, Growth, Nutrition and Cultivation—II. Assimilation of Carbon, Oxygen, Hydrogen and Nitrogen—III. Function of Mineral matter in Plant Production—IV. Typical Fertilizers—V. Comparative cost of Farmyard and Chemical Manure—VI. Waste Portion of Crops Important as Fertilizers—VII. Past and Present Systems of Agriculture—VIII. Plant Production—IX. Analysis of the Soil by the Plants themselves—X. Farming with Farm Manure only—XI. Formulæ for Manures—XII. Effects of Farmyard Compared with Chemical Manure—XIII. Live Stock—XIV. Live Stock—XV. Agricultural Industry.

The Apendix covers sixty pages and contains tables, analysis, and results of Experiments.

A PRACTICAL TREATISE ON HIGH-PRESSURE STEAM BOILERS. By WILLIAM M. BARR. Indianopolis: Yohn Brothers. Price, $4.

This book presents a record of the author's experiments, notes, memoranda and practice during several years. Much of the practical information has never before been published. The chapters treat separately of:

1. Introduction—II. Cast Iron as a Material for Boilers—III. Wrought Iron as a Material for Boilers—IV. Steel as a Material—V. Testing Wrought Iron or Steel for Boilers—VI. Riveted Joints—VII. Welding, Flanging and Influence of Temperature—VIII. Strength of boilers—IX. Heating Surface and Boiler Power—X. Externally Fired Boilers—XI. Internally Fired Boilers—XII. Boiler Setting—XIII. Feed Apparatus—XIV. Heaters and Economizers—XV. Safety Apparatus—XVI. Incrustation and Corrosion—XVII. Sectional Boilers. 204 cuts illustrate the text.

ELECTRIC LIGHT: Its Production and Use. By G. W. URQUHART, C. E. Edited by F. C. WEBB, M. I. C. E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand Price $3.00.

The rapid development of the various methods of producing electric illumination excites a general interest in the subject, and leads to demands for carefully-prepared works relating thereto. At the present time, as much sound knowledge is required to determine what among recently current literature to discard as what to accept as a part of the authentic history of the subject. The present work possesses the merit of a carefully-compiled account of the batteries, dynamo-machines, and lamps which have been brought forward as late as April of this year. The chapters treat separately of:

I. Introduction—II. Voltaic Batteries—III. Thermo-Electric Batteries—IV. Magneto-Electric Generators—V. Electro-Magnetic Machines—VI. Dynamo-Electric Machines—VII. General Observations on Machines—VIII. Electric Lamps and Candles—IX. Measurement of Electric Light—X. Mathematical and Experimental Treatment of the subject—XI. Application and Cost of the Electric Light—Tables Relating to the Several Machines.

Ninety-four well-executed cuts illustrate the text.

WOOD-WORKING MACHINERY: Its Rise, Progress and Construction. By M. POWIS BALE, C. E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $5.00.

This work relates, as its title indicates, entirely to a single branch of practical technics.

The illustrations, which are numerous, are confined to the designs of English, French and American engineers.

MISCELLANEOUS.

HERR OBACH proved, a few years since, that alloys of the metals proper, such as lead and tin, potassium and sodium, and sodium amalgam, conduct a current without being decomposed. Herr Elsässer has recently (*Ann. der Phys.* No. 11), experimented with combinations of metals with the half-metallic elements, antimony and bismuth, passing a current through the fused alloy in a glass tube with electrodes of gas carbon. There was here also no decomposition. The author notes that the transition from these compound conductors, of the first class to the electrolytes, is no sudden one. Between the two groups are substances, which at a low temperature conduct without decomposition, but at a high one, and even partly before they melt, are electrolyzed, *e. g.* copper and silver sulphides, and the

sulphides of lead, nickel, iron, bismuth, tin and antimony. To this middle class, also, may be added a number of compounds, which have not hitherto been electrolyzed, probably because they are so difficult to fuse (such as the oxides of tin, iron and chromium); the electrolytes proper do not conduct without being electrolyzed; and to this class belong especially the haloid compounds of the metals, which are not decomposed in the solid state because they are insulators; whenever they begin to conduct, being fused, they are decomposed. Lastly there is a fourth class of compounds, which in general do not conduct, either with or without decomposition.

Cost of Tunneling.—The cost of some of the chief tunnels completed since the commencement of the railway system is as follows:—

Name.	Place.	Material.	Cost p.yard run.
Limehouse.........	Footway underThames	London clay	£ 30
Lydgate...........	L.& N.-W. Ry.	Coal. meas.	30
Guildford..........	L. & S.-W. Ry.	Chalk	30
Salisbury..........	Ditto	Ditto	30
Petersfield.........	Ditto	Ditto	30
Netherton.........	Birm.Canal.	Marl	39.25
St. Catherine's....	L. & S.-W. Ry.	Sand	40
Honiton....	Ditto	Marl and green sand	50
Bletchingley	S.-E. Ry.	Clay	72
Buckhorn Westor.	Sal.& Yeo.Ry.	Clay	72
Chicago...........	U.S.A.	—	88
Batignolles........	Paris	—	95
Box................	Gt.West. Ry.	Oolite & marl	100
Saltwood..........	S.-E. Ry.	Sand	118
St. Gothard........	—	—	122.7
Kilsby..	L.& N.-W. Ry.	—	145
Thames...........	—	Clay and silt.	1299

Builder.

Bonsilate.—One of Newark's (N. J.) latest industries is the establishment of a company engaged in the manufacture of a new product intended to substitute ivory, hard rubber and kindred substances employed in the manufacture of a variety of useful or decorative articles. The material is said to be composed chiefly of finely ground bone, which is agglutinated by the addition of some cementing compound. From the peculiarity of the name, we should suspect this to be silicate of soda, though our account states that it is at present the secret of the manufacturers. The name of J. W. Hyatt, which is mentioned as one of the inventors of "bonsilate," will be recognized as that of one of the inventors of the singular composition known as "celluloid,"

The manufacture of this new product is said to have progressed so far that already a large variety of articles are made of it and placed upon the market. The material can be molded in dies like any other plastic composition. It can be formed into slabs, bars or sheets, which can be turned, polished, or sawed into desired shapes; and by the addition to it of various coloring pigments, a variety of costly and decorative substances, such as coral, jet, malachite, colored marbles and other stones, can be closely imitated with it.

From the account given, it must, like celluloid, possess a high degree of elasticity, as one of the leading companies of this city is reported to be making billiard balls of it. In addition, it is being used for cane and umbrella handles, checkers and dominoes, door knobs, buttons, clock cases, and the like, in imitation of the costly marbles.

A number of other projected uses for the new product are given at length, but those we have named will suffice to give an idea of its probable utility. From the very imperfect account given of its composition, we should incline to the opinion that "bonsilate" promises to be a very cheap substitute for the materials above named, but we doubt if it will be found adapted for as great a diversity of uses as celluloid.

Progress in Utilization of Solar Heat.—Since May last year, M. Mouchot has been carrying on experiments near Algiers with his solar receivers. The smaller mirrors (0.80 m. diameter) have been used successfully for various operations in glass, not requiring more than 400° to 500°. Among these are the fusion and calcination of alum, preparation of benzoic acid, purification of linseed oil, concentration of sirups, sublimation of sulphur, distillation of sulphuric acid, and carbonization of wood in closed vessels. The large solar receiver (with mirror of 3.80 m.) has been improved by addition of a sufficient vapor chamber and of an interior arrangement which keeps the liquid to be vaporized constantly in contact with the whole surface of heating. This apparatus on November 18th, last year, raised 35 liters of cold water to the boiling point in 80 minutes, and an hour and a half later showed a pressure of eight atmospheres. On December 24th M. Mouchot with it distilled directly 25 litres of wine in 80 minutes, producing four litres of brandy. Steam distillation was also successfully done, but perhaps the most interesting results are those relating to mechanical utilization of solar heat. Since March the receiver has been working a horizontal engine (without expansion or condensation) at the rate of 120 revolutions a minute, under a constant pressure of 3.5 atmospheres. The disposable work has been utilized in driving a pump which yields six litres a minute at 3.50 m. or 1200 litres an hour at 1 m., and in throwing a water jet 12 m. This result, which M. Mouchot says could be easily improved, is obtained in a constant manner from 8 a. m. to 4 p. m., neither strong winds nor passing clouds sensibly affecting it.

Regnier's Battery.—A very promising new voltaic battery has been devised by M. Emil Regnier, the young Parisian electrician who invented the incandescent electric lamp known by his name. It may be generally described as a Daniell cell in which the sulphate of zinc solution is replaced by a solution of caustic potash. In detail, it consists of a zinc plate immersed in a solution of the alkali, and a copper plate immersed in a solution of the copper salt; the two solutions being separated by a porous partition of parchment paper made up in the form of a square bag. The electromotive force on charging this cell is 1.47 volts,

falling to 1.35 volts after it has been on "short circuit" for a considerable time. The internal resistance is 0.075 ohms. for a cell 5 in. high, and 12 cubic inches in capacity. According to tests made by M. Regnier the power of the battery for performing work, either by producing heat, mechanical power, or electrolysis, is twice greater than that of the ordinary Bunsen cell of physical laboratories. Moreover, the battery emits no volatile products, and its waste liquor may be regenerated by electrolysis into the original materials.

THE SAINT GOTHARD TUNNEL.—An unforeseen and very serious difficulty in the successful completion of the St. Gothard Tunnel recently declared itself. This was the sinking of the work over a length of about 100 yards, and to such an extent that it defied every effort on the part of the engineers to repair the repeated settlement of the roof. The formation at this unfortunate section consists of strata of gypsum and calcareous and aluminous schists, which absorb moisture very freely, and swell and disintegrate. So great was the trouble with this length that the almost desperate remedy of diverting the course of the tunnel so as to avoid it was seriously contemplated, and may even yet be necessary, although a method is now being adopted which promises extremely well. The dangerous portion is being enlarged and lined with granite walls, arching and invert, of great thickness. This lining, however, is not continuous, but built in independent lengths of about 12 ft. each, so that the settlement which ensues may affect only a short distance of the work. In commencing this labor the engineers first built the two end sections so as to obtain a sound abutment against the secure part of the lining, and from them lengths were advanced on each side towards the center. The thickness of the masonry at the center of the arch is 4 ft. 8 in., at the springing 8 ft. 3 in., and that of the invert is about 2 ft; only two more sections remain to be finished, five on the north and five on the south side having been completed. A Geneva correspondent writes:—"The engineers of the St. Gothard Tunnel seem to be in a fair way to overcome the difficulty arising from the falling in of the roof in the part known as the "windy stretch." This stretch, which is 200 meters long, and situated almost directly under the plain of Andermatt, passes through strata composed alternately of gypsum and aluminous and calcareous schists, which absorb moisture like a sponge, and swell on exposure to the atmosphere. It has given the contractors immense trouble, and has fallen in so often that it was seriously proposed a short time ago to allow it to collapse, and make a bend, so as to avoid the "windy stretch" altogether. The expedient now adopted, which has so far been successful, is the rebuilding of the supporting masonry in rings of solid granite. The rings are each four metres long, so that in the event of any one of them giving way the others will not thereby be affected. The building is constructed slowly and with the utmost care; no imperfect stones are allowed to be used; the masonry is perfect, and the walls of extraordinary thickness—in the parts most exposed to pressure not less than ten feet. At the beginning of June only 34 metres of the "windy stretch" required to be revaulted. The stories that have lately been going the round of the European Press touching the condition of the great tunnel, and the improbability of its being opened for traffic during the present year, would therefore appear to have little if any foundation in fact."

PRESERVING WOOD.—To a German technical journal, Privy Councilor Funk has contributed a valuable paper on the result of some experiments in preserving sleepers on the German and Austrian railways. The methods employed for impregnating the sleepers are well known, and the substances used were chloride of zinc, sulphate of copper, corrosive sublimate, and creosote. The latter is commonly used in this country, and from the manner of carrying out the process it becomes rather expensive. Herr Funk gives a table of the cost for oak, beech, and fir sleepers, from which it appears that the chloride of zinc is cheaper than the other preservatives, but costs more for beech than for either fir or oak. As compared with creosote, the only thing that gives an equal degree of durability, chloride of zinc, is about one-third the price, and the effect of impregnation is to bring fir sleepers into practical equality with the more costly woods. The life of sleepers, both impregnated and unimpregnated, depends largely upon the nature of the timber, and the manner in which the timber is treated before being made into sleepers, and the nature of the ballast in which the sleepers are laid; but by dealing with large numbers of sleepers employed under different conditions a fair idea can be obtained of the value of preservative processes. According to Herr Funk the average life of unimpregnated sleepers on German and Austrian railways up to the present time has been as follows: oak, 13.6; fir, 7.2; pine, 5.1; beech, 3.0 years.

On the same lines the average lives of sleepers properly treated and impregnated with chloride of zinc or creosote under heavy pressure have been: oak, 19.5; fir 14 to 16; pine, 8 to 10, beech, 15 to 18 years.

The prolongation of the life of the beech sleepers by impregnation is remarkable. Herr Funk adds that the average life of 831,341 pine sleepers impregnated on various systems, and used on thirteen German railways, was fourteen years.

Timber felled in winter is found to make more durable sleepers than that felled in summer, but what difference there is, is less marked in the impregnated sleepers than in those made of unprepared wood.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXLII.—OCTOBER, 1880.—VOL. XXIII.

ON THE STABILITY AND STRENGTH OF THE STONE ARCH.

By GEORGE F. SWAIN, S. B., Providence, R. I.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE theory of the stone arch has been so often discussed during the past few years that a new treatment of the subject may seem superfluous. Various methods of treatment have been proposed, differing greatly in the fundamental principles on which they rest, while in some those principles have not been clearly stated. Some authors treat the subject with the aid of statical principles alone, while others apply the theory of elasticity exactly as they would apply it to an arch of iron. It is believed that this latter method of treatment, while theoretically correct, is open to objections in practice, and that its results cannot be depended upon for absolute accuracy, while other methods are generally accompanied by an uncertainty, to dispel which various unscientific hypotheses have been proposed. Under these circumstances it may not be out of place to take up the subject once more, and to endeavor to show clearly the fundamental principles on which the stability and strength of arches depend. It is believed that the basis for a more satisfactory treatment of the arch than any heretofore proposed, is afforded by a theorem which was first demonstrated by Prof. Dr. Winkler, of Berlin—an authority well known in this country—and published in the "*Zeitschrift des Architekten und Ingenieur Vereins zu Hannover*" 1879, page 199, and that it enables us to arrive at a method of testing the stability and strength of stone arches, which is at least as accurate as any heretofore used, without being encumbered with any uncertainty. This method is at present the one perhaps more extensively used than any other, being, in fact, nothing more than the old method of endeavoring to construct a line of resistance within the middle third of the arch ring, but it is believed that the only satisfactory basis for that method yet proposed is offered by the theorem above referred to. Theorems somewhat similar have been at various times asserted without demonstration, and they will be referred to in the sequel. The bearing which they have on the theory of the arch has also been remarked, so that this article contains little new in itself. These various views and demonstrations have not, however, so far as the writer knows, been collected together into a succinct theory.

The stability and strength of any kind of an arch, of stone or of iron, depend upon the position of a certain line, called the *line of resistance*. Confining ourselves to the usual case in which the axis of the arch ring lies in a plane, in which plane also the outer forces act, the line of resistance will be a plane curve, and may be defined as the locus of the centers of pressure on each section perpendicular

to the plane of the outer forces, and (in general) to the axis of the arch ring. It may be constructed as follows: Supposing that on any section AB, at right angles to the axis, the real force acting: P, is known, in amount, direction, and point of application, S; then in order to find the real force P, acting on any other section CD, we compound P with the outer force F acting on the part ABDC of the arch, and the resultant of these forces is P_1. Its intersection S_1 with CD is the center of pressure on that joint, or the point through which the resultant of the stresses on that joint must pass. In making this construction for the stone arch it is usual to consider, not the whole arch, but a strip of it whose width is one foot, and the arch is thus composed of a series of these strips laid side by side, the section of each strip being a rectangle. The load being supposed

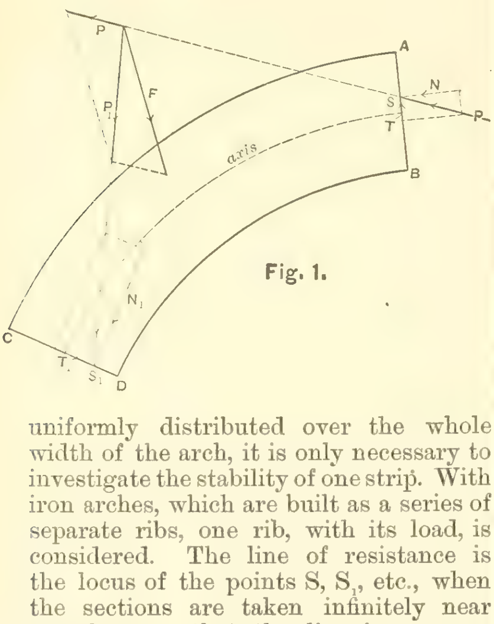


Fig. 1.

uniformly distributed over the whole width of the arch, it is only necessary to investigate the stability of one strip. With iron arches, which are built as a series of separate ribs, one rib, with its load, is considered. The line of resistance is the locus of the points S, S_1, etc., when the sections are taken infinitely near together, so that the line is a curve. The sections are generally taken normal to the axis of the arch ring (which is considered to lie in the plane of the paper) but in cases where there are well marked joints of separation between the pieces composing the arch—as in the stone arch, where the joints between the voussoirs form such dividing surfaces—these joints are taken as the sections used in finding the line of resistance.

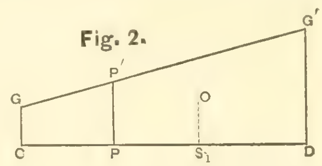
From Fig. 1 it is clear that having given the force P on AB, we can find the force P_1 on any section CD, whether normal to the axis or not. We shall suppose, however, the joints to be normal to the axis of the arch ring.

If we resolve the forces P, P_1, and F, horizontally and vertically, P into V and H, P_1 into V_1 and H_1, F into V_{11} and H_{11}, then the condition that P_1 is the resultant of P and H is expressed by the equations

$$V_1 = V + V_{11};\ H_1 = H + H_{11} \quad . \quad . \quad . \quad (1)$$

The state of stability and strength of any arch is deduced from the position of its line of resistance by the aid of the hypothesis of Navier, which supposes the normal component of the stress on any joint to vary uniformly from some line of no stress, called the neutral axis. The position of the neutral axis may be found for any given case with the aid of the theory of elasticity,* but in the case of the stone arch it will, under the assumptions made regarding the outer forces, always be perpendicular to the

Fig. 2.



plane of the axis. If we resolve P_1, then, into two components, N_1 and T_1, N_1 acting through S_1 at right angles to CD, and T_1 along CD, and if we lay off at each point P of CD a line PP′ representing the intensity of the normal stress at P, all the points like P′ will lie in a plane which intersects CD in a line perpendicular to the plane of the paper. The area CD G′G will represent N_1, and if from the center of gravity O of that area we draw OS_1 at right angles to CD, P_1 will pass through S_1, or S_1 will be the center of pressure on CD. The distribution of T_1 over the section CD may be also found by the theory of elasticity, with the aid of some assumptions, but it is generally not done in discussing the stone arch.

Thus if we have given the form P acting on a given joint, the determination

* See an article by the writer "On a General Formula for the Normal Stress in Beams of Any Shape." VAN NOSTRAND'S MAGAZINE, July, 1880.

of the distribution of the normal stress over that joint is reduced to the problem of drawing the line GG′ so that the area GG′DC shall represent the normal component, N, of that force, and its center of gravity shall lie on the line of action of N. This problem may be solved in many ways. The following solution may perhaps serve to illustrate as well as any other the distribution of the stress: Let the rectangle CDD′C′ repre-

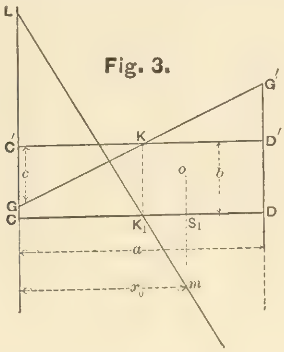


Fig. 3.

sent N, and let CD$=a$: CC′$=b$. Since the trapezoid CDG′G must represent N, it must equal CDD′C′, or GG′ must pass through K, the middle point of C′D′. Let C′G$=c$. If C$s_1=x_0$ we must have Nx_0 or $ba.x_0$=moment of GG′DC about C, or

$$ba.x_0=\frac{ba.a}{2}-\frac{a}{2}\cdot\frac{c}{2}\cdot\frac{a}{6}+\frac{a}{2}\cdot\frac{c}{2}\cdot\frac{5a}{6}.$$

Hence

$$bx_0=\frac{ba}{2}+\frac{ca}{6}\,;\quad c=\frac{6b}{a}\cdot\left(x_0-\frac{a}{2}\right)\quad . \; . \; . \; (2)$$

Writing this as a proportion,

$$c:3b::x_0-\frac{a}{2}:\frac{a}{2}.$$

Hence the following construction: Make CL$=3b=3$CC′, and draw LK_1 through the middle point of CD. OS_1 produced gives S_1M$=c$, which being laid off at C′G, GG′ may be drawn at once. For the similar triangles CLK_1 and K_1S_1M give S_1M : CL :: K_1S_1 : CK_1 or

$$c:3b::x_0-\frac{a}{2}:\frac{a}{2},$$

as required by eq. (2). From this construction we learn all that is necessary in regard to the connection between the stresses and the position of the line of resistance. The following cases may be distinguished:

1°. If $S_1K_1=o$; then $c=o$. Hence the stress is uniformly distributed.

2°. If S_1D$=\frac{1}{3}$CD; then $c=b$. Hence there is no stress at C, and that at D is represented by $2b$.

3°. If S_1 lies between the two positions just mentioned, there is a positive (compressive) stress on all parts of the joint.

4°. If S_1D$<\frac{1}{3}$CD; then $c>b$, hence there is a negative stress, or tension at C. The mortar of the joints is able to bear a certain tensile stress, but for safety it is generally assumed that it can bear none. Hence the stress will be distributed over a distance equal to three times S_1D, according to 2°, the remainder of the joint being without stress.

5°. If S_1 approaches near enough to the edge D, the stress at that edge will be greater than the crushing strength of the material.

6°. If S_1 falls outside of the joint it is clear that there can be no equilibrium, and the arch will fall—the mortar being supposed without tensile strength.

Hence the *condition of equilibrium* of an arch is: *the true line of resistance must fall within the arch ring at every point.*

A consideration of the crushing strength of the material makes the *condition of strength* take the following form: *The true line of resistance must not approach near enough to either edge of the arch ring to crush the stone at that edge.* The limit may be found as follows: Let s be the smallest value of S_1D. The stress is distributed over $3S_1$D or $3s$, and the greatest stress, that at D, has the value $\frac{2N}{3s}$, or twice the mean pressure, and this must equal the crushing strength of the stone, C. Hence we have

$$\frac{2N}{3s}=C \text{ or } s=\frac{2N}{3C}\quad . \; . \; . \; (3)$$

which enables us to find C when N is known.

In practice, it is advisable that the whole surface of each joint should be subject only to compression, in order that there may be no tendency for the

joints to open. This leads to the following condition, which may be considered the basis for the treatment of the arch: *The true line of resistance should everywhere lie within the middle third of the arch ring.*

But whichever of the three conditions stated above be laid at the bottom of the method of treatment, it is clear that the stability and strength of the arch depend on the position of the *true* line of resistance. We have shown how to draw the line of resistance when the force acting on one joint is known. Suppose that force assumed, and the line of resistance drawn lying within certain limits. In general, other lines of resistance may be drawn within the assumed limits, and of all possible lines of resistance the true one must be found before any conclusions whatever can be drawn relating to the stability and strength of the construction—or at least, limits must be found within which the true line of resistance must be proved to lie.

Before proceeding further, it will be well to consider for a moment what outer forces may act upon the arch.

The outer forces may be vertical or inclined, the horizontal components of inclined forces being due to resistance of the spandrils, or to earth pressure. With regard to the latter, it does not exist in many cases, except in those of tunnel-arches, and arches under railroad embankments. It must of course be taken account of in investigating the stability of the arch. With regard to the former, however, opinion seems to be divided regarding the advisability of taking account of it, some authors neglecting it altogether, and some considering that it is capable of supplying the horizontal *thrust* necessary to sustain in equilibrium a linear arch parallel to the intrados of the proposed arch and similarly loaded. The resistance of the spandrils is an element of stability, and that it will act, as the arch ring tends to deform under the action of the loads to which it is subjected, is not to be denied. Its amount, however, cannot be determined, and will evidently depend upon the execution of the spandril walls and backing, the thickness of the joints, etc., and will increase as the deformation of the arch ring increases. In view of these facts, it is the opinion of the writer that it should be left out of account in investigating the stability, and that the arch should be constructed so as to be stable without its assistance. We shall refer to this point once more. In case no horizontal forces act on the arch ring, the horizontal component of the force acting on any joint is constant through the whole arch, while in cases where the outer forces are inclined, that component varies, as shown by equation (1).

Now suppose that, starting with a given force on a given joint, the line of resistance be drawn. By varying the assumed force, in amount, direction, and point of application, other lines of resistance may be drawn, and in general an infinite number of them may be constructed within the limits adopted. To determine which of these lines is the true one, various hypotheses have been made. Some writers have assumed that

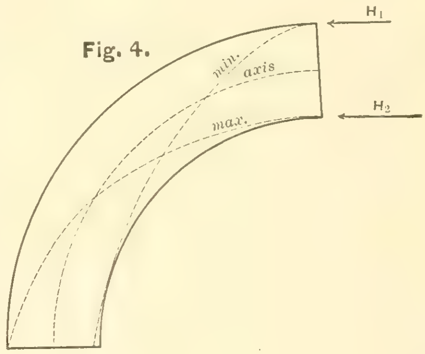


Fig. 4.

one to be the true one which gives the smallest absolute pressure on any joint in the arch. Others have taken as the true one the one lying nearest to the middle line of the arch ring, that is, the one whose average distance from the middle line is the smallest. Others call in the aid of the "principle of least resistance," and declare that were the arch stones incompressible, that line of resistance would be the true one for which the horizontal component of the stress on any joint—and hence on each—is a minimum consistent with stability, and that the effect of the compressibility of the arch stones is simply to cause the line of resistance to retreat slightly within the arch ring at points where it would otherwise reach the edge. It is

not the intention to develop here the rinciple relating to lines of resistance with minimum and maximum horizontal thrust, but we will simply state that it may be easily proved that the line of resistance with the maximum horizontal thrust, which is possible without the corresponding line of resistance passing out of the arch ring, or the maximum line of resistance, as we shall call it, must touch the extrados at two points, and the intrados at one higher intermediate point, while the minimum line of resistance must in general touch the intrados at two points, and the extrados at one intermediate point.* These two lines deviate, then, as far from the axis of the arch as it is possible for them to do without passing outside of the arch ring. For symmetrical arch and loading, the lines of maximum and minimum horizontal thrust will have positions something as shown in the figure. By starting with the minimum line of resistance, with the thrust H_1, and by gradually increasing H_1 and lowering its point of application in the crown, we arrive at last at the maximum line of resistance. Both deviate as far as possible from the middle line of the arch ring—the axis—but in opposite directions, so that we know that in passing from one to the other, with some intermediate thrust and point of application at the crown, the corresponding line of resistance must have been on the whole nearer the axis than either the maximum or minimum line of resistance, and the same is true for unsymmetrical arch or load.

There seems, then, to be little unity of opinion among authorities regarding the position of the true line of resistance, although on its determination the whole theory of the arch depends. On considering the subject closely, however, it is clear that the line of resistance will have a fixed position, determined by the elasticity of the material. It is well known that this is the case with the iron arch, and between the iron arch and the stone arch there is no essential difference, so far as the theory is concerned. The effect of the elasticity of the material is not simply to move the line of resistance a little toward the axis of the arch ring at those points where it would, according to the principle of least resistance—which itself admits of dispute—touch the extrados or the intrados, but that effect can only be investigated mathematically, and it is not possible to say beforehand what it will be. The application to the stone arch of the principles of the mathematical theory of elasticity offers, it is true, great difficulties. We have here to do with a non-homogeneous elastic arch, an arch whose modulus of elasticity is not constant, but varies between that of stone and that of mortar; an arch, moreover, whose section and moment of inertia are, in many cases, not constant; and by a mode of construction often employed the arch and its abutments are made as one piece, and both must be considered together as forming one elastic rib. Further, the determination of the axis may offer some difficulty, for, the axis being defined as the locus of the centers of gravity of sections perpendicular to itself, these sections cannot be fixed in position until the axis is known, while the axis itself depends upon the position of the sections. The process of finding the axis is hence a tentative one. And the process of determining the line of resistance may also be a tentative one, on account of the fact that the sections are not exactly known. If a joint opens, only that surface on which the stress acts can be considered as forming the section, so that if we assume at first that all joints remain closed, and find that our resulting line of resistance in fact passes in some places out of the middle third of the arch ring, the process would have to be revised. But if the joints open, we encounter a new difficulty, for although only the bearing surface at each joint can be considered as the section at that point, it would obviously be incorrect to suppose the section to vary suddenly to that of the full arch ring; for although the methods of treatment of elastic arches of varying section do not require the section to vary continuously, yet were that not the case the

* A full discussion of the properties and construction of lines of resistance may be found in "Scheffler—Theorie der Gewölbe, Futtermauern, und eisernen Brücken—Braunschweig, 1857. Equations to the lines of resistance and their tangents, with some of their properties in "Dupuit—Traité de l'équilibre des voutes, et de la construction des ponts en maçonnerie—Paris, 1870." An account of Scheffler's investigations and results, with remarks on the application of the theory of elasticity to arches, in Cain, a practical theory of voussoir arches. New York. Van Nostrand's Science Series, Nos. 12 and 42," first published in this Magazine.

laws of elasticity on which those methods are based would probably not be exactly correct. How far the results obtained would be invalidated by the circumstance, we cannot say, but incline to the opinion that the effect would be very small. Again, the elastic treatment of the arch requires the sections to be perpendicular to the axis, while in many stone arches the joints lie obliquely. Further, a want of homogeneity of the mortar may be accompanied by serious effects; a small pebble of very hard stone might suffice to make the line of resistance pass through itself, acting, as it were, the part of a hinge on the joint where it occurs. The true position of the line of resistance would be further influenced by the action of the center, its rigidity, and the mode of loading it to prevent deformation, the method and rapidity of striking the centers, the yielding of the abutments, and so on. But, assuming that the mortar is homogeneous, that the joints are thin, and that disturbing elements are as far as possible eliminated, the line of resistance might be at least approximately determined, though it would be a tedious process. Nevertheless, as eminent an authority as Prof. Winkler advocates the elastic theory of the stone arch, and it is clear that theoretically it is the only theory leading to an accurate insight into the condition of any part of the arch, but the practical difficulties referred to above would be sufficient, it seems to the writer, to render the results for the most part illusory, which, as will be shown, much simpler methods can lead to correct results regarding the stability and strength of the construction. The application of the theory of elasticity to stone arches has, in fact, been considerably discussed in late years. The first mention of such a treatment of the arch occurs, so far as the writer knows, in Winkler's "Lehre von der Elasticität und Festigkeit," and since that work appeared various papers and works on the subject have been published, some of which are mentioned below.* Prof. Keck, the editor of the "*Zeitschr des Arch.-und Ing.-Ver zu Hannover*," in a notice on the article of Perrodil, said that on account of the fact that the original stresses (stresses which the unloaded arch must be supposed to have) are not known, the application of the theory of elasticity is not correct, and the "rough method" which has hitherto been used is on the whole to be preferred. Méry (annales des ponts et chaussées, 1840) said, speaking of the true line of resistance, that it can only be determined "par des considerations plus on moins incertains sur les effets du tassement, Mais cette recherche n'est mullement necessaire, ainsi que l' on vient de le voir, pour être assurée de la solidité de la voûte." But this he does not prove satisfactorily. Prof. Cain (Theory of solid and braced elastic arches, VAN NOSTRAND'S MAGAZINE, Nov. 1879) also suggests the application of the theory of elasticity to arches, as leading to the most exact solution of the problem of their strength. He considers it unnecessary for testing their stability, since the arch "cannot fall until all of its cases of stability are exhausted." The writer is unable to see but that in order to be sure that the arch is stable, it is necessary to know the true line of resistance, just as much as to be sure that it is strong enough. It seems to him that Winkler's theorem is the basis of both strength and stability. Prof. Greene, in Part III. of his work on trusses and arches, applies the theory of elasticity to stone arches just as to iron arches. The results thus arrived at are approximately correct, but the process is a tedious one if it is applied rigidly, even based on the supposition of a homogeneous material and a constant section.

We have allowed ourselves to be drawn somewhat at length into the consideration of the application of the theory of elasticity to arches of stone, because it is a question now under discussion. We hope that the theorem which will follow, and which are derived from its principles, will suffice to show that it is not necessary to apply it in practice.

Steiner—Allgemeine Bauzeitung, 1874—Über Theorie der Bogenbrücken" (after Winkler's lectures).

Hübl—Allgem. Bauzeitung, 1878—Graph. treatment of circular arch of constant section and fixed ends. (After Steiner's lectures).

Perrodil—Annales des ponts et chsussées, 1872 and 1876. (Only for symmetrical loading).

Winkler—Deutsche Bauzeitung, 1879 and 1880—Über Lage der Stützlinie im Gewölbe."

Greene—Trusses and arches, anal. and discussed by graph. methods. Part III. Arches.

With respect to the principle of least resistance, which has been so extensively applied of late, the writer hopes at some future time to present some reflections. For the present he will only state that he considers the principle essentially a false one, and that applied to the determination of the true line of resistance in the arch, it gives fallacious results. The true line of resistance can only be found by the theory of elasticity. Having shown that the stability and strength of the arch depends on the position of that line, we proceed to state and demonstrate the following theorem due to Winkler:

"*For an arch of constant section that line of resistance is approximately the true one which lies nearest to the axis of the arch ring, as determinea by the method of least squares.*"

We say, *approximately*, it will be seen that the theorem is not true if that word

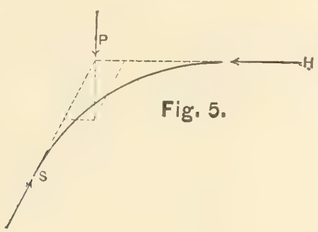


Fig. 5.

be left out. Further on, we shall try to show that the error is small, and does not invalidate the application of the theorem. The proof is as follows:

The *first supposition* is that *the loading is vertical.* We have elsewhere noticed that this supposition is not always true. The differential equation of the *equilibrium curve* (not the line of resistance) for giving loading is

$$\frac{d^2\mu}{dx^2}=\frac{q}{H} \quad . \quad . \quad . \quad (4)$$

when q=load per running foot at the point in question, H=Horizontal thrust of the arch, which is constant, μ and x =the condinates, horizontal and vertical.

For at any point S of the curve the resultant of the horizontal thrust H and the total load on the arch between the point in question and the point when the equilibrium curve is horizontal acts along the tangent at S, hence

$$\frac{d\mu}{dx}=\frac{P}{H} \text{ and } \frac{d^2\mu}{dx^2}=\frac{1}{H}\cdot\frac{dP}{dx}=\frac{q}{H}.$$

Integrating eq. (4) we find

$$\mu=A+Bx+\frac{f(x)}{H} \quad . \quad . \quad . \quad . \quad (5)$$

where A and B are constants, and $f(x)$ some function of x depending on the loading.

If y is the ordinate of the axis of the arch ring at S, referred to the same coordinate axis, then the vertical distance of the equilibrium curve below the axis of the arch ring will be

$$\mu-y=A+Bx+\frac{f(x)}{H}-y \quad . \quad . \quad . \quad (6)$$

The *second assumption* is that the line of resistance may be considered to coincide with the equilibrium curve. On this supposition eq. (6) gives the distance between the axis of the arch ring

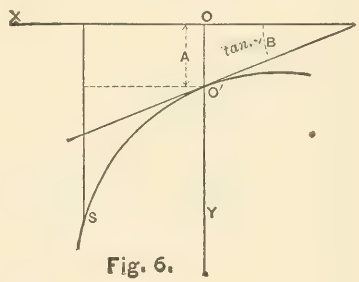


Fig. 6.

and the line of resistance. We shall consider these assumptions farther on.

Let us now examine the conditions necessary in order that the line of resistance may approach as near to the axis of the arch ring as possible, that is, the conditions under which the sum of the squares of the *vertical deviations* is a minimum. This sum $S=\Sigma(\mu-y)^2$ will be a minimum when $S_1=\int(\mu-y)^2\,ds$ is, that is, when the first differential coefficients of S_1 with respect to the arbitrary constants A, B, and H, are equal to zero. Now we have

$$\frac{dS_1}{dA}=\frac{2dA\int(\mu-y)ds}{dA} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\frac{dS_1}{dB}=\frac{2dB\int(\mu-y)x\,ds}{dB} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$\frac{dS_1}{dH}=\frac{-2H^{-2}dH\int(\mu-y)f(x)ds}{dH} \quad . \quad . \quad . \quad (9)$$

Hence the conditions for a minimum S_1 are

$$\int(\mu-y)ds=o \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$
$$\int x(\mu-y)ds=o \quad . \quad . \quad . \quad . \quad . \quad (11)$$
$$\int f(x)(\mu-y)ds=o \quad . \quad . \quad . \quad . \quad (12)$$

Since $f(x)=H(\mu-A-Bx)$ the last condition takes the form

$$\int\mu(\mu-y)ds-A\int(\mu-y)ds-B\int x(\mu-y)ds=o \quad . \quad . \quad . \quad . \quad (13)$$

or, with regard to (10) and (11)

$$\int\mu(\mu-y)ds=o \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Now we have, from the properties of the equilibrium curve, $\mu-y=\frac{M}{H}$, if M is the moment with respect to the axis, hence the above conditions may be written

$$\int Mds=o \quad . \quad . \quad . \quad . \quad . \quad (15)$$
$$\int Mxds=o \quad . \quad . \quad . \quad . \quad (16)$$
$$\int M\mu ds=o \quad . \quad . \quad . \quad . \quad (17)$$

Since $\mu=y+(\mu-y)$ the last equation may be written

$$\int Myds+\int M(\mu-y)ds=o, \text{ or}$$
$$\int(\mu-y)yds+\int(\mu-y)^2ds=o \ldots (18)$$

and since $(\mu-y)^2$ is to be a minimum, the last tern will be small compared with the first, and may be neglected, so that the last condition becomes

$$\int(\mu-y)yds=o, \text{ or } \int Myds=o \quad . \quad . \quad . \quad (19)$$

The three equations (15) (16) and (19) are known to be the three equations which determine the position of the true equilibrium polygon for flat arches of constant section with fixed ends, as deduced by the theory of elasticity. Hence our theorem is demonstrated under our assumed conditions, which we shall now proceed to consider a little more in detail.

It must be admitted that this demonstration is not so rigid as could be desired, yet it is believed that upon examination it will be found more accurate than it at first sight appears. The first assumption upon which it rests was that the loads act vertically. If we assume inclined loads we meet with difficulty, because we cannot bring the equation of the equilibrium polygon into the form given by eq. (5). In that equation A is the ordinate at the origin, B the tangent of the angle with the x axis at the origin, and $f(x)$ the moment about S of the load between that point and the origin. Since those loads act vertically their moment is of course only a function of x, and would be the same were S anywhere on the ordinate on which it lies, that is, $f(x)$ does not depend on H at all. But if the forces acting on the arch between S and O′ are inclined, the moment of their horizontal components will depend on the ordinate of S, and hence on H, and the equation to the equilibrium polygon takes a form different from eq. (5).

The second assumption was that the equilibrium polygon can be taken to coincide with the line of resistance. This may in some cases involve considerable error, but by a few changes which do not affect the equations, the investigation may be to a great extent freed therefrom. To find the ordinate y of the equilibrium polygon for an abscissa x, we must compound the force acting at the crown, P, with the weight and load on ACFB. To find the center of pressure on the joint DE we compound P with the weight and load acting on ABEDC. The assumption that the line of resistance coincides with the equilibrium polygon involves, therefore, as regards the outer forces for each joint, an error equal to the weight of a prism of stone like DEF. This error will be zero for a vertical joint, and in general will be zero at the crown of the arch, and will attain its maximum value at the springing. Compared with the load really acting on DE, however, the weight of the prism of stone DEF will be in general very small, so that the error from this source will, as Scheffler has remarked, be very insignificant when compared with the error involved in the fact that to find a point in the equilibrium curve we find the intersection of a certain line with DF, while to find a point in the line of resistance we find the intersection of almost the same line with DE. The true line of resistance and the curve found by determining the intersection with each joint as DE of the resultant of P, and the corresponding load on ABFDC, will lie very near together, but the equilibrium curve may diverge considerably from these lines. This difficulty may be in great part

avoided by the following considerations: Let D′E′ be a joint at a very short distance from DE. Project S and S′ on the axis of x at G and G′, and lay off GN, G′N′, so that the area of the rectangle GGN′N equals, to some assumed scale, the load acting on the part of the arch DEE′D′. The writer is well aware of the difficulties attending the exact determination of the distribution of the loads through the spandril walls on the arch ring, but in absence of any exact knowledge it is best, as it is usual, to consider the loads to be carried directly downwards, so that if DC represented the intensity of the load acting directly above D, the force on DD′ would be represented by DD′CC′. If we perform the construction just indicated for all points of the axis we obtain a curve $N_0 N_1$ such that any area $A N_0 N_2 G_2$ represents the load acting between the crown and the joint through S_2, the point on the axis directly below G_2. The equilibrium curve for this load would be represented by eq. (5), and to find the point corresponding to the joint DE, for example, we should compound P with the true load between the crown and this joint, and find the point where the resultant intersects GS. The proof of Winkler's theorem is not changed, while we have entirely got rid of the error due to the prism DEF, and partly rid of the error due to taking an intersection with DF instead of with DE. It is believed that this new equilibrium curve may be taken to coincide with the line of resistance, especially in the case of the true line of resistance.

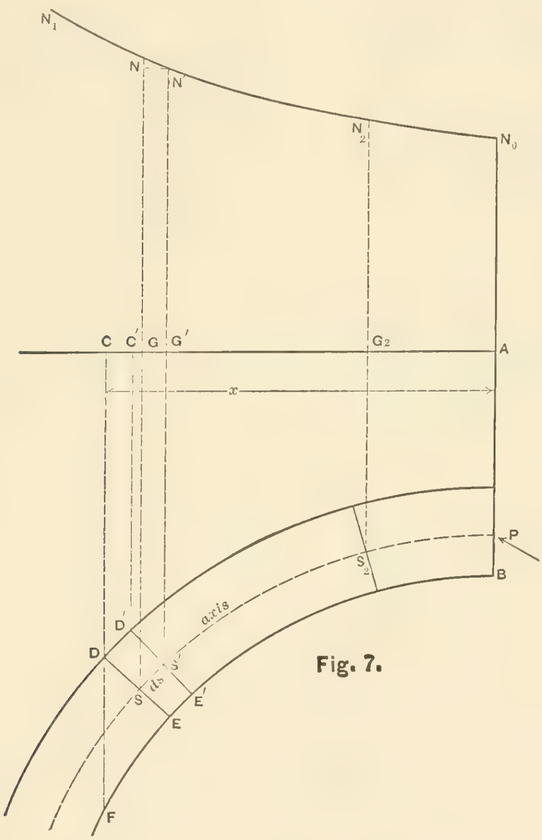


Fig. 7.

We have measured the deviations of the line of resistance from the axis vertically. It may be thought that they should be measured normally. To do so involves some difficulties, and it is reasonable to suppose that if the sum of

the squares of the vertical deviations is a minimum, the sum of the squares of the normal deviations will be a minimum too.

We have assumed that the conditions above found correspond to a minimum. There is no need to examine whether it does not represent a maximum, for a glance convinces us that the function in question has no analytical maximum.

The equations (15), (16) and (19) are only approximately the conditions determining the position of the equilibrum polygon, for arches of constant section. The exact conditions are the following, for any arch:

$$\int M_1 ds = o;\ \int M_1 y ds - \int P_1 dx = o;$$
$$\int M_1 x ds + \int P_1 dy = o,$$

the origin being at one of the abutments, and in which

$$M_1 = \frac{M}{EI} + \frac{M}{EFr^2} + \frac{P}{EFr};\quad P_1 = \frac{P}{EF} + \frac{M}{EFr}$$

I being the moment of inertia, and F the area of the section, r the radius of curvature, E the modulus of elasticity, M the moment and P the axial force. For circular arches of constant section these become *

$$\int M dx = o;\quad \int M dy = o;$$
$$\int \left(M + \frac{I}{Fr^2 + I} Pr \right) ds = o.$$

For flat arches r is large and P in almost all cases may be neglected, so that we easily find the approximate equations (15), (16), (19).

Assuming the truth of Winkler's theorem, in the case of arches subjected to forces slightly inclined and whose section is not exactly constant, we are enabled to state generally the theorem. *If any line of resistance can be constructed inside the arch ring, the true line of resistance lies within it also, hence the arch is stable.* For if any line of resistance can be so constructed, we can construct the maximum and minimum lines of resistance, and some intermediate line will be nearer to the axis than either of these two, as has been remarked above. It is true that it does not follow that because the maximum and minimum lines recede from the axis as far as possible at several points the sum of the squares of the deviations in each case is greater than in the case of any intermediate line, but in fact the lines of resistance are generally regular and continuous curves, so that it is believed that this will be the case in fact. We may also assert: *If any line of resistance can be drawn within the middle third of the arch ring, the true line of resistance can also be drawn within the same limits, hence no joint will tend to open.* It may perhaps be best, however, to take a margin of safety, to provide for the various contingencies which can affect the true line of resistance, and to increase the depth of the arch ring a little above the depth given by the above condition, as suggested by Prof. Cain.

* See Allgem. Bauzeitung, 1878.

And, finally, in order to be assured of the strength of the arch, it will be sufficient to proceed as follows: Draw a line of resistance for the given loading, making it pass through the centers of the joints at the crown and springing. This may be considered an average line, and will enable us to find, nearly enough, the force acting on each joint. Then calculate by mean of eq. 3 the smallest value of S_1D, and laying it off at each joint from both extrados and intrados, we have two curves within which the true line of resistance must be made to lie, that is, between which we must be able to construct a line of resistance. These lines, however, will generally lie outside of the middle third of the arch ring.

For the investigation of the frictional stability of the arch, as well as for the details of the graphical construction of lines of resistance, we must refer to the books of Sheffler and Cain.

If the element of stability offered by the resistance of the spandrils be neglected, as in the above, it will be found in many cases that in order to confine the line of resistance within the inner third of the arch ring, particularly in the case of arches which are semi-circular, or nearly so, the thickness of the arch ring must be very great at the springing. In view of this fact, such arches are often built with the backing carried up, with squared vertical and horizontal joints, to the joint of rupture, or joint below which a thrust from without is necessary for the stability of a linear arch similar to the given one.

This joint will usually lie between the points when the inclination of the axis of the arch ring to the horizon is 45° and 60°. The part of the arch ring below the level of the top of the backing is considered as forming a part of the abutment, and only the part above that point is considered as forming the arch proper. There seems to be no objection to this treatment, although the cost of carefully carrying up the backing to points about 45° from the crown, may perhaps form quite an item, but it may be noticed that inasmuch as this method renders it unnecessary to investigate arches extending more than 60° each way from the crown, it forms an additional argument in favor of basing the theory of the stone arch on Winkler's theorem, which for such arches may be considered as practically accurate. For arches which are not flat the equations on which it is founded are, as noticed above, not exactly correct, and the flatter the arch, the more do they approach absolute accuracy.

In conclusion, a few historical notes regarding theorems somewhat similar to Winkler's may not be out of place. *

Hagen, in 1844 and 1862, said that the question was to determine the line of resistance which affords the greatest safety, though he does not assert this to be the true one. He finds that line of resistance for which the absolute pressure on the most compressed joint is a minimum, but his supposition regarding the distribution of stress along a joint is incorrect. It may be remarked here that the supposition we have made will be also incorrect if the arch ring is composed of several concentric rings having no bond with each other. Such a construction is not advisable, because each ring will act for itself, and it cannot be determined how the load is distributed among the several rings.

Hänel, in 1868, determined the position of the *most favorable* line of resistance, as he called it, according to the same principle, but based on the correct distribution of pressure on a joint. He also does not assert that this will be the true line of resistance. This assertion, however, was made by Drouets in 1865, who called the principle a metaphysical one, and said that the molecular resistances would so adjust themselves that the greatest absolute pressure in the arch would be a minimum.

That the principle is a metaphysical one, few will deny, but its incorrectness is shown by the fact, noticed by Dupuit, that it leads to the supposition that the reactions of the supports of a continuous girder must be all equal. Durand Claye gave in 1867 a graphical treatment according to Drouet's principle.

Culmann, in 1866, asserts exactly the same principle. He was followed in 1875 by Du Bois in this country. He says that of all possible lines of resistance the true one is the one which lies nearest to the axis, so that the pressure at the most compressed edge is a minimum. His proof is, if the material is so weak and the arch ring so thin that only one line of resistance is possible, which does not cause a rotation or a crushing of the material, then this is the true one. If now the material gradually hardens, no change can take place, hence this line of resistance must be the true one for any material. This assumes the theorem that if only one line of resistance is possible, it is the true one, which has not been proved. In fact, the principle that the true line of resistance is the one involving the smallest maximum stress supposes, as it were, a certain power of thought in the material, together with an endeavor to exert only as much force as is absolutely necessary. However reasonable this may seem by its analogy with cases in which power of thought is present, it has not been proved. The principle has been humorously called "the principle of the foxiness of the material." (Das Princip der Schlauheit des Materials.)

The principle that if any line of resistance is possible in the middle third of the arch ring, the true one lies in the middle third, and hence no joint will have a tendency to open, was stated by Harlacher in 1870. This assertion is disputed by Winkler, in 1879, who says it is not in general correct. It seems to the writer, however, to follow directly from Winkler's theorem.

Cain, in 1879, says that it "seems

* For historical notes on the theory of the stone arch, the reader is referred to Scheffler, pp. 203-232, and to two articles by Winkler, Deutsche Bauzeitung, 1879 and 1880. "Über Lage der Stutzlinie im Gewölbe." From the latter most of the above notes have been taken.

highly probable that the actual line of pressures is confined within such limiting curves, approximately equi-distant from the center line of the arch ring, that only one curve of pressures can be drawn therein, corresponding, therefore, to the maximum and minimum of the thrust in the limits taken." This he does not prove, however, but it agrees, in a general way, with our conclusions.

To sum up, then, it would seem that the theory of the stone arch is comprehended in the following theorems:

1°. The stability and strength depends upon the true position of the line of resistance, which can only be found by the theory of elasticity.

2°. On account of the various contingencies which may in practice disturb the position of the line of resistance, its exact determination is impossible.

3°. The principle of the theory of elasticity show, however, that the true line of resistance is the one lying nearest to the axis of the arch ring.

4°. Hence it is not necessary to apply the principles of that theory in detail, inasmuch as if any line of resistance can be drawn within the middle third, and at the same time within the limiting lines for crushing, then the arch will possess sufficient stability and strength.

THE INSTITUTION OF MECHANICAL ENGINEERS.

From "The Engineer."

INAUGURAL ADDRESS OF THE PRESIDENT, MR. E. A. COWPER.

I do not propose on the present occasion to trouble you with any long history of the progress of mechanical engineering, as various matters press themselves very urgently on our notice at the present time, and demand, it appears to me, very serious reflection on our part. I allude of course, firstly to the very great and general depression in trade that has now held its dull course for years; and, secondly, to the means in our power that are, or are not, being taken advantage of to promote the manufactures and commerce of the country. Now, I am not one of those who would, for a single moment, think of sitting quietly with one's hands before me, and saying, 'If foreigners choose to do the work which we have been in the habit of doing exclusively for many years, and thus take away our trade, we cannot help it, as we cannot prevent them from becoming better educated in manufacturing arts than they were.' But let us examine the situation frankly and fully, and see the reasons of the changes that have undoubtedly taken place; and we shall find that one of the primary causes consists in the fact—which I ventured to allude to on a previous occasion—that during the thirty years' war on the Continent, very little attention, comparatively speaking, was given to manufacture, because the populations were much engaged in preparing for fighting, and in actual warfare, and in tilling the ground for a bare subsistence. But before considering the present era, let us glance—and glance only—at the fact, that in by-gone times it was much the fashion, if some ingenious engineer were required for a special work, such, for instance, as making a dock, or a bridge, draining fens, or other public works, to call in a Dutchman, or an Italian, or other foreigner, so that we must not say that in those days England always produced just the men that were wanted. I think it is advantageous and wholesome for us sometimes to look around, and to examine and reflect on what has made this country the manufacturing and successful country that it is, and what is now wanting to enable us to continue to hold that proud position securely. I am well aware that some thinking men consider that technical education, such as is given in Germany, is what is wanting in this country, and, although I think much more than this is needful, I give all honor to the earnest men who are striving to promote technical education in London, and in all the large cities and towns of England. But I most emphatically call

the attention of manufacturers generally throughout the country—not to mechanical engineers only—to the advantages that they would reap, if they generally and sysematically threw more enterprise into their business, and showed greater interest in investigating and adopting new improvements in manufactures. I will attempt to illustrate my meaning, and to cite a few examples of real enterprise, and the immense effects they have had on the manufacture, the commerce, and the very position of this country amongst nations. Take for instance the new manufacture which has made this important town, and is its chief industry—and is, in fact, the cause of our being assembled here to-day. I allude, of course, to the Bessemer manufacture; and one reason why I call it 'the Bessemer manufacture' is, that we owe not only the invention to its author, but also the introduction of the steel when made into the market. For it is well known that manufacturers had not the enterprise to take up the invention and prosecute it to a perfect success, until Sir Henry, then Mr. Bessemer, and certain capitalists had spirit enough to go into the business; when, with the further assistance of Mr. Mushet's manganese, it was soon an accomplished fact, that good steel could be made in immense quantities at a cost altogether unheard of before. Here we see gentlemen altogether outside the trade, giving the country an essentially good thing, and providing work for thousands of our artisans. The introduction of the Siemens process for very mild steel also deserves especial notice, and the steel is in great demand. I believe it is to such efforts as these, and to such enterprise as we shall see developed here at the steel works, the shipbuilding works, the docks, the jute works, &c., that we may look for the retaining and increasing of our trade and commerce. I wish to allude to a few other inventions and enterprises, which every thinking man must admit have had a like effect on manufactures and commerce; and I must at the same time, and in common justice, mention other cases in which the British manufacturer has, I am sorry to say, been lamentably behind in the race of improvement. I have in my lifetime seen the whole of the railways in the kingdom under construction, with the exception of the Stockton and Darlington, and the Liverpool and Manchester; and the latter I went down to see the first year after its construction, so that I have taken note of a very large number of what are commonly called 'modern improvements;' and I may, perhaps, also name a few of those that were young when I was a lad. There is no doubt but that we are largely indebted to our rich natural resources in mineral wealth, such as coal, clay, lime, salt, stone, iron, lead, copper, tin, &c., whilst another very important factor is the natural wit and industry of the English character, which is so different in many respects from the lethargic, volatile, or idle character of some other nations; and I argue that, in view of these facts, it would, indeed, have been a shame, if many good, new, and useful results had not been produced, though I maintain that many more might have been generated, had more enterprise and less conservatism in old ways been shown.

One of the earliest and most marked improvements, in the conveyance of merchandise of all kinds inland, was the large development of canals by Brindley, at once reducing the cost per mile from about 10d. to 1d.; so that the materials produced in one part of the country were able to be transferred to other parts, where it was possible to utilize them; and merchandise could also be conveyed to large towns or ports for shipment. This improvement tended largely to develop the resources of the country, and greatly to assist those who were principally dependent upon agriculture. The successful exertions of Smeaton in improving water wheels and windmills did much to supply the country with power for grinding and pumping, as well as for forge and tilt hammers, and for blowing engines in ironworks; but the amount of water power available in the country is comparatively small, far too small too meet the necessities of manufactures. The next vast step in improvement was undoubtedly the introduction of the steam engine, first by Newcomen, simply for pumping, and secondly by Watt for general purposes, thereby immensely stimulating the old manufactures of the country, and giving rise to many new ones. The

case of Watt is one which clearly shows the advantage of the patent laws in stimulating invention, by enabling the inventor to reap a portion of the advantage of his own discovery; for it was distinctly the fact of his having a patent that caused his money partner, Boulton, to persevere in bringing the invention to bear on an extensive scale. And here, in passing, I may call attention to the fact that fourteen years was not enough to develop the most useful invention of our times, and that another fourteen years was given. The service rendered also by Trevithick, in the introduction of the high pressure steam engine, was much more important than is generally acknowledged; it certainly is not universally known that he ran a locomotive engine on a circular railway about 1804, in Euston square. I may mention that my own father saw it running there, inside an inclosure, and it ran round so fast as eventually to leave the rails. The progress of improvement in manufactures after the invention of Watt was brought to bear was much more rapid. Cotton spinning was quickly improved; Arkwright introduced his spinning frame; Crompton introduced his mule, and Roberts his self-acting mule; and finally, Cartwright introduced the powerloom. The manufacture of soda from common salt was introduced, and was a most valuable invention. The papermaking machine was invented; bleaching and dyeing were much improved. The printing machine was brought to bear, and at once spread knowledge at the rate of 1,200 large sheets per hour, printed on both sides, in place of small sheets, only printed on one side, at 250 per hour. I trust you will excuse my mentioning this in honor of my late good father. A little later the Jacquard or figuring loom was brought forward; steam navigation, and later on, ocean steamers, were a complete success; and pottery and porcelain were much improved in various ways. Then came the grand strides made by railways, and the consequent cheap and quick conveyance of passengers and materials in all directions, thus enabling numbers of industries to be established and worked with advantage, and giving employment to tens of thousands. In shipping, it only required experience of the entire success of the first iron ships, the Garry Owen, and Aaron Manby, to give iron ships a firm footing, though the advocates of wooden ships delayed their introduction for a time. At the present time, the immense advantages obtained by the introduction of mild steel in shipbuilding are increasing the shipbuilding trade of this country in a remarkable degree. The great economy with which steamships can now fetch and carry minerals of low value, in enormous quantities, throughout the world, combined with the immense facilities afforded by railways, enables almost any kind of material to be transferred from any one spot on the globe, where it may be produced, to any other point where it may most economically be utilized, and where real improvements in manufactures may be made. As an example, some of the most sulphurous copper ores of South America, formerly not worth transport, are now used in immense quantities, owing to the invention of the Gestenhofer furnace, in which the burning of the sulpher from the powdered ore accomplishes its calcination. The sulphurous vapor thus produced is used to make sulphuric acid, and the acid employed to make soda out of common salt. I merely mention this as one instance among hundreds in which several different manufactures have been improved at the same time by one simple invention. Telegraphs then came to our aid, to facilitate the interchange of information, and particularly did ocean telegraphs help greatly in the more important communications between continents. I must not here dwell upon the immense variety of telegraph instruments and appliances; but the great acceleration accomplished by duplex and quadruplex signalling, through one wire in both directions, has been a marked improvement of our age, and contrasts strongly with Professor Wheatstone's original four wires, with the rails of the railway, as was supposed, for a return wire. Passing on to the most recent improvements, we shall see, for the first time in England, liquid steel, in ingot moulds, submitted to the pressure of high pressure steam, in order to compress the bubbles of carbonic oxide, or carbonic acid gas, in the mass, and so render the ingot more sound; on the same principal as is

employed by Sir Joseph Whitworth when he uses hydraulic pressure. Another very interesting manufacture which we shall have full opportunity of seeing, is the jute manufacture, which has risen to such large proportions, that some manufacturers have moved their establishments to India, where the jute is grown, and where labor is very cheap; whilst the recent use of the stump, or lower part of the jute stalk, for paper making, has gone some way to reduce cost. Wire rolling mills are also to be seen in the neighborhood, where lengths of a quarter or even half a mile can be rolled out from one billet ready for being drawn. There is, likewise, a Hoffman kiln for burning bricks in the most economical manner, by utilizing the heat of bricks that have been burnt for heating up bricks to be burnt. The large docks, with immense concrete retaining walls, and their large gates and other appliances, will be found well worthy of attention; and Joy's new slide motion will demand careful consideration, particularly in reference to its application to locomotives, an excellent specimen of which has been brought here by Mr. Webb, with the motion applied in his own way, and with the last improvement in a slide valve, which gives a double quick opening at the beginning of the admission. I must not dwell on other improvements in machines and manufactures which have certainly helped the commerce of this country, such as the preservation of food, stereotype printing, preparation of india rubber, fog signals, gas manufacture, photography, weaving, plating, metals, machine tools, candle making, lace making, tea rolling, machinery for lifting weights, hydraulic machinery, interlocking railway signals and points, railway brakes, writing instruments, sugar machinery, both cane and beet, bolts and nuts, screws, locks, anchors, steam hammers, lead and iron pipes, blast furnaces, gun cotton, dynamite, nitro-glycerine, steel masts and yards, steering apparatus, economical engines, microscopes, telescopes, spectroscopes, thermometers, for discovering icebergs at sea, artificial leather, agricultural implements, sinking piles by means of a jet of water, fire engines, &c.; and I may, perhaps, add to these Sir Henry Bessemer's high temperature furnace, with gases under pressure, and Dr. Siemens' elegant experiment of melting steel in a crucible with the electric current, and his plan of stimulating the growth of plants. Perhaps you will be inclined to ask me why I have thus con jured up to your mind's eye a number of inventions and improvements which you know have helped to make England's greatness; for this reason, that I want manufacturers to appreciate much more than they do at present, that such vast improvements having been made, further important steps can be taken, so as to keep England always in advance of all other nations in manufactures and the arts, if only more enterprise and energy are shown in taking up known good things, inventing new processes, and prosecuting them to success. For instance, sewing machines ought to be made here, and I urged English makers years since, to go in thoroughly for making every part accurately and by machinery, so as to fit together at once without "fitting," but I could not get this carried out, and now sewing machines come from America literally by millions, though labor is dearer, metal is dearer, and there are upwards of 3,000 miles of carriage against them. But "machine manufacture" is cheaper and better than "hand making." In gun making I counseled some of the Birmingham makers, years before they did anything in the matter, that they would actually lose their trade if they did not adopt good machinery to manufacture every part exact to size; and, at last, when the Government had the means of doing most of the work, they did adopt machinery, but many years too late. Then, with regard to common pumps, they are now imported from America by thousands, and are sold here without being commonly known to be American; clocks and watches also come in immense numbers, some of them very cheap and common, whilst others are very well made. Another trade, nearer, perhaps, to most of us, is that of rolled iron girders, which, I am sorry to say, are coming by hundreds and thousands from Belgium; indeed, almost every house, that is now built in London with rolled iron girders, is supplied from Belgium. These things should not be; we have iron in plenty, and labor in abundance, but we

want special machines, schemed as fast as they are wanted, to fit the work properly, and turn it out accurately in large quantities; and we should show more enterprise in adopting a good "new thing," which I am sorry to say is what some of our old-fashioned manufacturers are slow to do, often little knowing how they damage the trade they are in by not adopting the best known process. Finally, I venture to think that one of the best results of our Institution meeting in various localities, from time to time, as we do to-day, is, that there is free intercourse between those who are in one line of engineering and those who are in another line; and that such comparing of notes and observations as naturally takes place in conversation is most conducive to the obliteration of prejudices and wrong notions, and particularly to the removal of the illusion, that what is now being done cannot be improved.

THE MANUFACTURE OF ALUMINIUM, SODIUM AND SIMILAR METALS.—A patent has been obtained by Mr. W. P. Thompson, of Tranmere, for a novel process of manufacture of aluminium, sodium and similar metals, which, if successful, would very greatly reduce the present high price of these metals. Liquid iron, either alone or in conjunction with hydrogen or carbon, is to be the reducing agent, and the operation is to be conducted in an apparatus similar to the well-known Bessemer converter. This apparatus is made up of two characters. After the iron has been fused in the one it is transferred into the second by turning the converter. Through a tube opening into this second chamber, hydrogen, or carburetted hydrogen, is allowed to enter, and through another one chloride or fluoride of aluminium in a state of fusion or as gas. Hydrogen and ferric chloride escape, and in the converter remains iron alloyed with aluminium and carbon. This mixture is again transferred to No. 1 chamber, where the carbon is to be burnt by a current of air. After transferring to No. 2 the process of reduction is to be continued until the iron is almost wholly consumed, when hydrogen alone is to be used as reducing agent. Thus an iron-aluminium alloy results. For the preparation of sodium hydrogen is not requisite. Iron, mixed with much carbon, is to be heated with caustic soda in the converter, and the sodium, said to be formed under these circumstances, is simply distilled off. When all the carbon is consumed the iron may be worked into Bessemer steel, or may be again recarbonized. Iron and potassium not forming an alloy the method is not well applicable for the preparation of potassium. For the manufacture of pure aluminium, sodium is to be preferred in the manner described, and then in the chamber containing the metal, chloride or fluoride of aluminium is to be allowed to enter, air being excluded. The chamber is provided with stirring gear, and is lined with alumina, or a mixture of lime, magnesia and alumina. The inventor will likewise apply his process to the preparation of magnesium, calcium, strontium and barium. (Patent 2101, March 27, 1879.)

FRENCH FIRE-DAMP COMMISSION.—A few months after Leverrier's death a commission was established for determining the best means of protecting colleries from fire-damp. The commission has written a very long report recording the causes of 420 accidents. Sixty-four projects presented by private individuals have been examined, and some new instruments have been designed and are being constructed, viz., an anemometer by Vicaire, a manometer by Le Chatellier, and a registered apparatus for the quantity of air introduced into the galleries. But the composition of coal explosive dust has not been determined, nor the extent of its influence upon catastrophes; while the chemical analysis of fire-damp has not been completed. The only substantial benefit is a compilation of mining regulations and a series of propositions which have been transmitted to the French Ministry, and will be laid before Parliament next session.

"ABYSSINIAN" TUBE WELLS.

By ROBERT SUTCLIFF.

From the "Journal of the Society of Arts."

The process of obtaining water by digging wells is of great antiquity, and that of boring scarcely less ancient. The particular method of obtaining water that it is the object of this paper to explain, is entirely modern. The crude idea of driving a tube into the ground for water is scarcely more than a dozen years old, and many of the appliances for driving tube wells are still more recent. In ancient days, wells were national property, and battles of possession have been fought over them. Now, a well can be made in many places in a few minutes, and the very deserts may be tapped, and clear springs obtained from them. Like many other clever inventions, the tube well owes its first existence to America, although it has been jocularly claimed as having been really originated by the negroes, who drove pointed bamboo canes into the earth, and slaked their thirst by drawing up the water through the pores of the cane. Be this as it may, the first iron tube well could only be driven in the very softest soils, and the tubes were struck on the head, which caused bending, injury to the screw threads, and fracture of the pipes. The pipes at first employed were also of inferior quality, such as are used for gas purposes, and were quite unsuited to the rough treatment and vibration that a tube well is subjected to. Upon the introduction of the patent into this country, the necessity for an improved method of driving the tubes became at once evident to those having charge of the invention.

This process it may be of interest to describe. In the first place, the materials used must be of the very best quality, and specially tough and good iron is required for the tubes. The first tube is pointed and perforated up for a few inches, with holes varying from one-eighth to quarter inch. The point is somewhat bulbous, but only sufficiently so to make clearance for the sockets by which the tubes are connected together. On the tube a clamp is fastened, provided with steel teeth, so as to grip the tube. This clamp is tightened by means of two bolts. Next, a cast-iron driving weight, or monkey, is slipped on to the tube above the clamp. The tube, thus furnished, is stood up perfectly vertical, in the center of the tripod; ropes are made fast to the monkey, and driving is commenced by two men pulling the ropes, and allowing the monkey to fall on the clamp. It is particularly important that the bolts of the clamp are kept tight, so that no slipping takes place. When the pointed tube has so far penetrated the earth that the clamp reaches the ground, the bolts are slackened, and the clamp raised again some two or three feet. Length after length of the tube is thus driven into the earth, being connected together by socket joints. It will be noticed that the tube well proper is, therefore, self-boring, and that no core of earth is removed.

One of the first questions that will suggest itself to a thinking mind is, will not those small perforations be blocked entirely up by being thus forcibly driven through the earth. This was the American's first idea, and he provided a sort of sleeve, in the shape of a sliding tube over the perforations, to protect them from the earth. Experience, however, has proved this protection to be quite unnecessary. The perforations are made about four times as numerous as is necessary for obtaining a full flow of water from the tubes. Earth does find its way into the tube-well in pellets, like the casts from a worm; but some of the perforations are always left sufficiently open to allow water to pass into the well, and if the soil comes rapidly into the tubes, it is easily mixed with water poured down from the surface, and drawn up by $\frac{1}{2}$-inch tubes, to which a pump is attached. To thoroughly clean and open the perforations, an ingenious contrivance has, however, been utilized. Long before the tube wells were invented, a pump was manufactured that, by lifting the handle, would allow the water to run out of the tail-piece, and thus prevent freezing in

winter. This sudden liberating of a column of water that is maintained above its normal level, is the method which is employed to clear out the perforations of a tube well. In skillful hands, the water can be kept in a state of agitation, being alternately allowed to press through the perforations, from the inside and from the outside; and before the whole column of water has descended to the level of the spring, it is caught up by the pump, and a fresh supply drawn into the tube. In this way the perforations are syringed, as it were, free from all soft obstructions, and the excess of holes over what is required, makes the closing of a few by grit which is too large to pass through, of no consequence. This action of the pump is not only useful in clearing the perforations, but in some soils it plays a most important part in the development of a supply. When all the holes are free, the fall of the column causes jets of water to disintegrate the earth, and by this means the finer and softer particles are pumped to the surface, and either an actual cavity is formed below, or, in gravel, a sort of filter bed is left, out of which all the sand within reach of the pump has been withdrawn. It should be stated, that the first presence of water in a tube well is ascertained by an ordinary plumb-line, which is also useful for gauging the quantity of earth in the tubes. Having got the tube well into the spring from which it is to draw the perforations all free, and the earth thoroughly disintegrated in the immediate neighborhood of the point, it remains to describe the method of pumping.

Until this plan of obtaining water was discovered, all pumping was done by means of a suction-pipe communicating with the well or bore-hole. As the atmosphere had free access to water in the well, the action of the pumps was simply to draw water out of the reservoir, and there its duty ended. The method of pumping a tube well is entirely different; all atmospheric pressure on the water in the tubes is removed at each stroke of the pump, and hence the supply is drawn to the spot, instead of simply flowing there by gravitation. Although the tube wells achieve this result as it were by accident, the importance of the fact is now generally acknowledged by engineers. Many engineers were of opinion that it would be impossible to obtain water at all, if the atmospheric pressure were excluded from the well, but they did not pursue their reasoning quite far enough. It is true there must be atmospheric pressure somewhere on the water that we pump from, but it need not be in the immediate vicinity of the well. Perhaps it is miles away. Pumping in this way, we have not the tiny reservoir of an artificial well, but in some cases natural underground lakes, one might almost say, seas of water, to draw from. Some here may recall how our army, during the Abyssinian war, was supplied with water by these tubes, and it was the prominence which that war gave to the invention that led to the present prefix to their name. For campaigning purposes the wells were only used singly, as one or two were found sufficient to supply the wants of a number of troops. When, however, large supplies for manufactories, towns and villages were needed, a fresh development in the system took place. Instead of single wells of great diameter, groups of moderate size were driven and coupled together by horizontal mains, so that powerful steam pumps could draw from many wells at the same time. The great friction that would be caused by drawing an enormous body of water to a single spot is thus avoided. Wells so coupled draw from a very large area of ground, and the water-level at any one spot is not so rapidly lowered. The very action of the pump, too, in drawing the water to the wells, opens and maintains channels of communication which help to keep up the level of the water. In putting down plant for a large supply of water, a trench, hundreds of feet in length, and some two or three feet in depth, is dug, and tubes are driven every twenty feet, and coupled by mains as already described.

It may be interesting to refer to some particular instances, where large supplies of water are thus obtained. At West Thurrock, in Essex, a cement company is pumping from two 5-inch tube wells, about 80 feet deep, 220,000 gallons per day of 10 hours. Another cement works at Northfleet is pumping 60,000 gallons per day. These have been pumped daily for about four years, and still give a

constant supply. As expense is an important feature, it may be mentioned that the cost of these did not exceed £60 each. The coupled tube wells are to be found in greatest numbers at the centers of beer manufacture, where abundance of pure and cool water is an absolute necessity. At Burton-on-Trent, about two million gallons are pumped daily from these wells.

A feature of particular interest to this Congress is the question of purity of water supply. Tube wells very soon attracted the attention of sanitarians, from the fact that, being forcibly driven into the earth, there is little or no possibility of their being contaminated by surface drainage. Too frequently a dug well, from defective steining or other causes, becomes little better than a cesspool. It is also often expensive work to dig through water which is impure, in search of pure springs below, and still more costly, when the good water is found, to keep the bad from mixing with it. Accidental and temporary contaminations are not infrequent in dug wells. One of recent date came to the author's knowledge, which was of so serious a nature, as to cause a Government inquiry. It was found that in a certain district, supplied by a water company, enteric fever was raging with great virulence. No less than 352 cases occurred in places supplied with this particular company's water. In a very exhaustive report to the Local Government Board, it was clearly proved that a contamination of the wells, caused in a peculiarly offensive and direct way, was the origin of the epidemic. The instances of tube wells having been driven through contaminated water, and tapping pure springs below, are very numerous. A few may be mentioned, where the results are not merely one of opinion, but are proved by analysis. At Gravesend, within a stone's throw of the Thames, a 2-inch tube was driven through contaminated water, and reached a spring at about 50 feet, from which a sample was taken, and submitted for analysis. The analyst, after enumerating the particular constituents of the water, pronounced it to be the purest he had ever analyzed, with the exception of Loch Katrine. Bear in mind that this was taken from a well situated in the last place one would expect to find pure water, namely, within a few yards of the River Thames, which at that point is quite salt, and charged with London sewage. A point has sometimes been raised, as to whether water obtained from such positions is likely to remain pure when regularly drawn from, and, perhaps, severely taxed. This particular well has been made between four and five years, and subsequent analyses have proved the maintenance of its good qualities. It is used for purposes which necessitate a very strict watch over its excellence. The ships at that port fill their store tanks from this well, the Royal yacht among the number, the quality of the water is not therefore taken for granted.

At Deal, another illustration of the perfect isolation of a spring was afforded. Most of the wells in that neighborhood are brackish, and a supply of fresh water was needed for a flour mill, and for domestic purposes. Within the first 25 feet water was found in gravel, but too salt for use. The miller was under the impression that if the tubes were driven deep, fresh water would be obtained, and he discouraged any further testing of the water on account of the delays in so doing, until 100 feet had been driven. At 117 feet the pump was again applied, but instead of being better, the water was as salt as brine. The engineer having charge of the work noticed that at the depth of 45 feet the water level differed both from that at 25 and that at 117 feet, and the fact suggested to his mind the desirability of testing the quality of this middle spring. A second tube was therefore driven to 45 feet, and from it quite fresh water was obtained. This happened five years ago, and the water still remains free from brackishness.

Hundreds of other instances might be mentioned, but these are so marked as to be sufficient for the purpose of illustration.

Some waters of good quality, but containing sulphate of lime, &c., are much injured by the exposure they get in ordinary wells, and the author has heard of dug wells at Burton-on-Trent that emit an unpleasant effluvia, and get unfit for use if not constantly pumped. This appears, therefore, an additional reason

for keeping the atmosphere from the spring.

When rock, solid stone, or incompressible clay is met with, a tube cannot be driven through it without first making a hole, and removing the cores. In some cases, however, there may be many feet of loose earth which can be easily driven through; this (especially if gravel has to be passed through) is a tedious process. The tubes, therefore, may be fitted with a temporary hard wooden point, which will allow them to be driven through the soft earth, and when an obstruction that cannot be penetrated is met, the point is knocked out, and, being wood and in sections, it floats to the surface of the water, and leaves an open-ended tube, through which ordinary boring tools can be passed to chisel and break up the rock. A tube can frequently be driven through gravel and clay to a depth of, say, 70 feet in a single day. To bore to the same depth in similar stratum frequently takes ten days or a fortnight. The saving that may be effected by driving through the loose stratum can, therefore, be readily appreciated, and, what is still more important, the upper part of the tubes are fixed more tightly in the ground than if a boring had been made to receive them. In some cases, however, hard strata come right to the surface, and the boring operation, consequently, cannot be deferred. When this is the case, instead of using a pointed tube, an open-ended steel shod pipe is driven into the hole as the boring proceeds. As the tools pass down inside the pipe they do not cut so large a hole as the outside circumference, and some little trimming down of the sides is left for the steel shoe to perform.

In great depths the single tier of pipes, with which the work is commenced, cannot be forced the whole way. Tubes, therefore, of smaller diameter are inserted; but, as to pump by the tube well method, air-tight joints are absolutely necessary, the final tube is continuous from the deep spring to the surface. In this way, tube wells 300 and 400 feet in length are put down, and if the spring, when tapped, rises to the surface, or within, say, 25 feet of it, only an ordinary lift-pump is required to obtain the supply. Where the water does not rise to the required height, a deep well pump can be lowered into the tube well, and worked by rods from the surface.

Bored tube wells are frequently put down in sets, and connected by horizontal mains, where large supplies are required.

The new water-works at the town of Skegness, in Lincolnshire, will be supplied by two bored tube wells thus coupled together. These wells are already completed, and a supply of pure water from the sandstone has been obtained, although salt water was passd through during the upper portion of the work.

In describing the method of driving tube wells in the commencement of this paper, mention has not been made of the latest system, which is more particularly applicable to tubes of large size. It is so simple as to merit a brief notice. An elongated cylindrical weight passes down inside the tube, and the blow, instead of being struck at the surface, is delivered where it is wanted, near the point which penetrates the earth. As water in the tube would impede the force of the blow, the first socket above the peforations is made sufficiently long to admit of a stout iron ring or washer being placed in the center of it, in such a way that the two lengths of tube, when screwed tightly together, butt against it, one on the under and the other on the upper surface. The interior of this ring is of sufficient size to allow the water to pass freely through it, but it has a screw thread cut throughout its whole length. During the operation of driving, the opening in this ring is closed by a steel plug, which is screwed down into it until its shoulder butts on the ring. The upper surface of the plug forms an anvil, on which the driving weight falls. The plug is readily removed and brought to the surface when the required depth has been reached.

The object of this paper has been to describe a particular method of obtaining water in large quantities, and free from contamination; but in the great question that this Congress is considering of National Water Supply, no one system can, under all the varying circumstances, be applicable. One town may have abundance of good water at its

feet, others may have to seek it and conduct it from a distance.

The collection of full information on this part of the subject is of the greatest interest and importance, and before a really national scheme of water supply is entered upon, it seems advisable that a complete hydrogeological survey of the whole country should be carried out.

Mr. Joseph Lucas has, for some time past, devoted special attention to this branch of geology, and has, single-handed, mapped out certain districts, and compiled much information into a compact and useful form. To carry out such a gigantic inquiry in a reasonable time, however, requires more assistance than a private individual can generally command, and, probably, it is in this direction that Government aid might, in the first instance, be most advantageously directed.

STEEL AND IRON FROM PHOSPHORIC PIG.

By C. B. HOLLAND and A. COOPER, Sheffield.

From "Engineering."

ON THE MANUFACTURE OF BESSEMER STEEL AND INGOT IRON FROM PHOSPHORIC PIG.

Before entering upon the subject of our paper, it might not be out of place to consider, for a moment, what is steel, and what is ingot iron. Steel has been defined as "an alloy of iron and carbon which is capable of being cast whilst in a fluid state into a malleable ingot," and all other elements usually found in the steel of commerce, such as silicon, sulphur, and phosphorus, may be regarded as impurities, and are more or less hurtful. In like manner, ingot iron may be defined as an iron which is capable of being cast whilst in a fluid state into a malleable ingot, and other elements found in it (including carbon) may in this case also be regarded as impurities. It follows, then, that those steels and ingot irons are the best and purest which contain the noxious elements in the least quantities, no matter whether they be produced from the finest brands of Swedish and hematite, or from common iron containing from 1¼ to 2 per cent. of phosphorus. And we think all will agree, if it can be shown that steel and ingot iron can be produced from the latter kind of pig of the same chemical composition, and capable of standing the same mechanical tests as that produced from the purer irons, that one is as good as the other for all purposes. It is not our intention to occupy the time of the Institute by referring to any of the numerous papers that have been written and the theories that have been propounded, during the last eighteen months, on the dephosphorization of iron by the Thomas and Gilchrist process, interesting and instructive as many of them are. It will be sufficient to say that, notwithstanding the great strides that had been made in the development of the process at the works of Messrs. Bolckow, Vaughan & Co., under the able direction of Mr. Richards (who must always be regarded as one of its earliest pioneers) and the very satisfactory results obtained by that company in the manufacture of steel from Cleveland pig iron up to the early part of November last, before we had seen the process in operation, there appeared to us certain difficulties which we feared would greatly retard its successful working from a commercial point of view. The first of these may be regarded as a technical one, and had reference to that part of the operation now well known as the "after-blow." Assuming, as we did, all the metalloids, with the exception of phosphorus and sulphur, to be oxidized before the commencement of this period, it seemed doubtful to us whether it would be practicable (having no definite point at which we could safely stop blowing corresponding to the drop of the carbon flame in the ordinary process) to burn out the whole of the phosphorus regularly, without sometimes carrying the operation too far, and thereby oxygenating the charge. And this, as all steel-makers will agree, is very apt to give trouble. Again, we had our misgivings about the gathering at the nose, concerning which we had heard so much,

and the delays which we thought must necessarily result from the indispensable and repeated turning down of the converter for sampling. It was at this time (early in November, last year) that we were invited to see the process, at the Hörde Works in Westphalia, and, through the courtesy of Mr. Pink, the manager of the steel works, our representative was not only shown the process in operation, but every information respecting the difficulties that had been experienced up to that time, and the means which had been employed to overcome them, was very kindly given to him by that gentleman. From the working at Hörde, it was apparent that the phosphorus was eliminated with regularity—there were no violent reactions on the addition of the spiegel, showing that the metal was not oxygenated to any great extent, and the steel made was of a mild quality, and very malleable. On November 20th, we commenced to work the process in Sheffield, using a mixture of white Lincolnshire and No. 4 forge irons. By sampling during the after-blow, we were enabled not only to remove the phosphorus in a very satisfactory manner, but also to make good and malleable steel; but the gathering of the slag and metal at the nose of the converter at first proved such an obstacle to rapid working, that although we employed men with long bars to fettle after each operation, at the end of from 12 to 18 blows, we were compelled to stop, allow the converter to cool down, and cut out the accumulation. At this early stage we were of opinion that by increasing the area of the nose, we should get a decreased pressure of gases, and consequently the slag and metal would not be carried up so high, and that this would remedy the evil. Our experiment proved to us conclusively the fallacy of this, for after altering the shape of our converter so that the area at the mouth was doubled, and lining up with basic bricks as before, although we worked under precisely the same conditions, this converter was completely slagged up at the nose, and was unfit for further work after ten blows, simultaneously with the other converter and with the mouth of usual size, lined with basic bricks. We tried admitting blast at the throat, with the view of burning the carbonic oxide, and so increasing the temperature at this point, but the results were not sufficiently encouraging to justify our following up the experiment. In the succeeding week we lined our converter nose with bricks made of silicate of soda and limestone, the other with ordinary fireclay bricks, contracting both at this point to a diameter of about 20 inches, or to about one-half the original area. In both cases we perceived at once a great improvement through the reduced size, the converters retaining their heat very much better than before. The slag still adhered to the first-mentioned slightly. It was easily removed by bars, but, unfortunately, usually carried a portion of the very brittle silicate of soda and limestone brick with it, and this form was abandoned on that account. The other converter with the fireclay bricks gave better results, and we have since used them regularly. What little slag adhered could be removed without any material injury to the lining. Although the common fireclay bricks then used wasted considerably, numerous experiments proved that the amount of silica carried down into the bath from them was too small to do any harm, and as the lining at this part was about 15 inches in thickness, we were able to get regularly from 30 to 40 blows before it got too thin. Thus, as far as the immediate nose was concerned, the difficulty seemed at an end, but we soon found that a great accumulation took place just below the junction of the fireclay bricks with those of the basic material, and also along the sides of the converter, in the form of a ridge of slag and metal left little by little on each turning down for the purpose of sampling. It seemed to us that to remedy this evil the simplest plan was to avoid testing as much as possible, if not altogether. All our results had shown that, notwithstanding the after-blow, the fully blown metal was not nearly so much oxygenated as at the end of the ordinary blow in the hematite process. Numerous analyses gave as the impression that this was due to the presence of manganese in the mixture we were then using, containing as it did about .75 per cent. of this metal, and we found invariably, that when we started with this quantity

there always remained from .1 to .2 at the expiration of the after-blow.

The following analysis show how much more readily (during this part of the operation) the phosphorus is attacked than the manganese:

	At the Drop of the Carbon Flame.	At the end of the After-blow.
	Per cent.	Per cent.
Blow 108 Phosphorus.	.883	.062
" " Manganese..	.443	.111
Blow 136 Phosphorus.	1.090	.044
" " Manganese..	.183	.147
Blow 166 Phosphorus.	.890	.081
" " Manganese..	.435	.194

These, amongst other results of a similar kind, led us for a time to think that it might be possible to eliminate the whole of the phosphorus by increasing the amount of manganese in the charge, and blowing with the spectroscope until the absorption bands—which one of our greatest authorities, Mr. Watts (see "Roscoe's Chemistry," vol. ii., part ii., page 77) on the use of this instrument has attributed to the oxides of this metal—had disappeared, for although our previous experience with mixtures containing .75 manganese had shown us that the bands always disappeared from the spectrum at the drop of the carbon flame, at which from .2 to .4 still remained, we thought it likely (assuming the above theory to be correct) that with a larger quantity we should be able to get rid of the phosphorus before these bands vanished. Accordingly, by means of ferro-manganese we increased the proportion of manganese in charge, No. 165, to about 1.75 per cent. At the drop of the carbon flame, when the bands disappeared, we found the composition to be:

	Per cent.
Sulphur	.118
Phosphorus	.955
Manganese	.817

The sample taken at this period hammered well, but, on testing in the usual way, proved very brittle indeed, and the fracture did not show the characteristic appearance indicating the presence of phosphorus, but resembled that of a very hard steel. On turning up the converter again for a further blow of thirty seconds, certain bands reappeared in the green portion of the spectrum for three or four seconds only; the composition at the end of this period was found to be:

	Per cent.
Sulphur	.155
Phosphorus	.831
Manganese	.612

The sample taken and treated in the same way as before was still exceedingly brittle, and resembled the former one. Again the converter was turned up, and for the space of one or two seconds only these bands again flashed across the spectrum, after which they were not observed during the remainder of the after-blow, although most carefully looked for. At the end of this period the test made was still hard, though much milder than before, and had the following composition:

	Per cent.
Sulphur	.132
Phosphorus	.460
Manganese	.576

The charge was then blown for a further 60 seconds, and as the sample, which was very malleable, did not harden, thinking that the fine crystalline appearance of the fracture, on breaking, was due to manganese, the heat was cast without the addition of spiegel or ferro-manganese. It showed no disposition to rise in the open top ingot moulds in which it was cast, and a tyre 2 ft. 8 inches inside diameter, made from one of the ingots, all of which hammered very well indeed, deflected 8 inches before breaking. Analysis of this steel or ingot iron, which showed that we had not carried the process quite far enough, gave the following composition:

	Per cent.
Sulphur	.114
Phosphorus	.146
Manganese	.440

From these results we drew the following conclusions: that the absorption bands usually seen in the spectrum of the Bessemer flame, are due to carbon, and that manganese bands (very similar in appearance to those of carbon) are apparent only when that metal exists in quantities of about 5 per cent.; and, further, that we could not hope, through

the agency of this metal, to determine upon any fixed point indicated by the spectroscope at which we could safely stop blowing, satisfied that the whole of the phosphorus was removed. But we had before noticed that with regular charges and conditions, the after-blow was of very constant duration, and the results of the blow showed us, not only that with 1.75 per cent. of manganese in the charge, in order to be quite sure of eliminating the whole of the phosphorus, we might safely blow rather longer (without risk of oxygenating) than the time actually required to effect this purpose, and thus avoid sampling, and afterwards, for rails, add a low spiegel or plate-iron to carbonize, but also that, if an ingot iron were required, it could be readily produced by the means described, without any such addition. Want of an iron containing anything like the amount of manganese prevented us from following up these results for some time, but, meanwhile, with mixtures such as we had, containing .75 per cent., we tried the effect of blowing after the addition of the spiegel, until the carbon bands, as seen through the spectroscope, had nearly vanished. The chemical analyses and results of a rolled bar from each of three such blows, tested, gave the following results. (See Table I.)

Three more blows made, amongst others, in the same manner, some weeks afterwards, gave the following results. (See Table II.)

The metal in all cases gave no trouble in casting into ingots (some indeed were cast in open top moulds from the top) and it was very malleable. Specimens of bars from blows 314, 329, 330, and 703 plunged into cold water at a red heat—some of which were afterwards bent and some twisted, cold—are exhibited. Having at length obtained some iron containing about 2 per cent. of manganese, a charge of this was blown alone, and, at the end of the after-blow of 130 seconds' duration, as the test taken was very malleable, and would not harden, the charge was cast into ingots without any addition whatever. The chemical composition of this charge, and the results of the mechanical tests are as follows. (See Table III.)

The heat as before gave no trouble in casting, and the steel was very malleable when worked at a high heat. Samples of the pieces submitted to tensile strain,

TABLE I.

Blows.	C. Carbon by Combustion	Silicon.	Sulphur.	Phosphorus.	Manganese.	Breaking Strain.	Elongation in 10 in.	Reduction of Area.
						tons.	per cent.	per cent.
314	.040	..	.065	.030	.356	24.20	26.875	51.78
329	.050	..	.045	.051	.240	26.48	29.375	65.59
330	.038	..	.069	.035	.266	24.18	26.250	59.04

TABLE II.

Blows.	C. Carbon by Combustion.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Breaking Strain.	Elongation in 10 in.	Reduction of Area.
						tons.	per cent.	per cent.
689	.061	..	.096	.051	.345		Not tested.	
703	.073	..	.091	.027	.370	24.49	31.25	49.79
						24.62	27.50	56.06
705	.101	..	0.70	.047	.468		Not tested.	

TABLE III.

Blow.	C. Carbon by Combustion.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Breaking Strain.	Elongation in 10 in.	Reduction of Area.
						tons.	per cent.	per cent.
748	..	..	.075	.030	.235	23.49	30.00	72.04
						23.49	28 25	70.01
						23.37	27.50	74.12

together with bars plunged into cold water at a red heat, and afterwards twisted and bent cold, as well as ordinary cold bends, are exhibited.

A second charge was treated in exactly the same way, except that, at the end of the after-blow, 15 cwt. of white hematite pig iron were added in lieu of spiegel. The resulting steel gave no trouble in casting, and an ingot hammered to test its malleability, worked very well. Analysis of the steel produced gave the following results:

C.C.	Si.	S.	P.	Mn. Per cent.
.55	Not estimated.	.107	.151	.612

It will be noticed that the phosphorus and manganese are higher—the former than it ought to be, the latter than one would have expected to find, after the addition of a non-manganiferous pig; but as the charge of white hematite was melted in a cupola which had only just before contained a 20 per cent. spiegel charge, we think it likely that a small quantity of this must have remained behind and come out with the white iron. With respect to the phosphorus, the mixture was one with which we had had little experience. It was also the last charge from the cupola, and, unfortunately, nearly a ton heavier than it should have been, which circumstance was not observed until it was poured into the ladle. And, although it was blown for 130 seconds after the disappearance of the carbon bands, exactly the same as blow 748, there is no doubt that it was under-blown, as the metal, before the addition of the white iron, contained as follows:

S.	P.	Mn.
.125	.147	.360 per cent.

For some time past, except in the case of the first two or three blows from a new mixture, when samples have been taken to determine the length of the after-blow, we have blown to time, and all testing during the operation has been dispensed with. It is true that our early results were not all satisfactory, but latterly, since we have used a mixture containing about C.C. 4.0 per cent., Si. .5 per cent., S. .2 per cent., P. 1.4 per cent., Mn. 1.0 per cent. in the converter, we have succeeded very well, as the results below will show. During the week ending April 10th, twelve test pieces, taken at random from the week's work, contained of phosphorus as follows:

No.	Per cent.	No.	Per cent.	No.	Per cent.
1	.103	5	.065	9	.111
2	.067	6	.070	10	.054
3	.040	7	.073	11	.074
4	.051	8	.052	12	.048

And in the week ending April 17th, when not a single sample was taken during the operation, except in the case of the experimental blow 748, the average amount of phosphorus contained in 36 blows, all of which were analyzed, was .056 per cent., the highest being .101 per cent., and the lowest .019 per cent. The composition of this quality of steel has been in other respects very regular, the analyses and results of a test-piece, 2 inches long and .533 inches in diameter, being as follows:

Carbon.	Silicon.	Sulphur.	Phosphorus	Manganese.	Breaking Strain.	Elongation.	Reduction of Area.
					tons.	per cent.	per cent.
.40	..	.040	.085	.662	39.75	20.25	31.84

Since the sampling during the operation has been dispensed with, there has

been comparatively little trouble with the slag adhering to the sides of the converter, and the wear of the lining has been practically uniform. As many as 87 blows, representing about 630 tons of steel, have been produced from one lining without any repairs whatever, except, after the 50th blow, new fireclay bricks to the nose; 37 more blows, equal to about 270 tons of steel, were converted in the same lining after renewing the front or blowing side, and putting in a third fireclay nose. At the end of our last week's work (April 17th), during which bricks made of the best pot clay were used for this purpose, instead of being scoured away as had been invariably the case with the commoner ones, they were little the worse for wear, and would, we feel sure, have run for a second week. The vessel bottoms (all made with a mixture of tar and lime rammed round pins) during this same week, averaged 8 blows each, the maximum being 12, and the minimum 4; but this bottom was taken out on completion of the week's work, and was very little worn. With respect to output, during the eight weeks ending April 17th (omitting Easter week, which was a broken one), 3380 tons of steel were made, or an average of 422 tons per week, the largest week being that ending March 27th, when 541 tons 7 cwt. were produced. In conclusion, we think it will be apparent to all that there are no difficulties in the working of the process. We are satisfied that as good steel can be produced by it from phosphoric pig, and quite as regularly as that obtained from hematite in the ordinary ganister-lined converter. We have shown that it is an easy matter to produce a malleable ingot iron, containing practically *no carbon* and very little manganese by this method, which, to say the least, is rather difficult from hematite pig by the old process; and, although our only experiment (results of which we have laid before you) to produce a harder quality of steel from phosphoric pig high in manganese, without the addition of any manganiferous pig, at the end of the operation did not turn out as satisfactory as we could have wished, there appears to us little doubt but that this too will be accomplished, as well as the production of soft steels suitable for boilers and ships' plates, &c., in a similar manner. It is true that our production from one pair of converters has never yet exceeded 541 tons 7 cwt. in one week, but it must not be forgotten that the process is still a new one, and that the plant at our disposal is not of modern construction, nor well adapted to its requirements. These requirements are, in our opinion (on account of the wear of the lining), either additional fixed converters, or duplicates with proper facilities for changing, as well as suitable arrangements for the speedy removal of the large quantity of slag. Under these conditions, in a well-arranged shop, we feel sure that not only as great an output can be obtained by the process as is now being produced in the best English practice in the conversion of hematite, but also that it may be made to equal anything that has ever been accomplished by our friends on the other side of the Atlantic.

AN ANCIENT ROADWAY.

From "The Builder."

ASSYRIAN AND EGYPTIAN MONUMENTS.

Long before conquering Rome had covered the ancient world with her net-work of military roads, Commerce and War, the sponsors of civilization, had thrown out their lines of communication which bound together the nuclei of culture. The name of one of the earliest cities of primitive times which the Bible makes known to us is Kharran, "the caravanserai," or "road city."* Hither Abraham had journeyed, following, no doubt, the "via publica" of those days, the commercial and military road which bound together the two seats of civilization, the one on the banks of the Euphrates, the other on the banks of the many-mouthed Nile. Few roads can rival, in antiquity or in historic associations, that

* Genesis xi. 31.

ancient pathway of culture which connected the capitols of Babylonia and Egypt, and along which was an ever-flowing stream of intercourse. Centuries ago, in a far remote past, the primitive Semite trader had wandered forth on his long and dreary journey to visit the cities of the "land of the setting sun." Months of traveling of danger from man and beast were before him; but his hand was against every man if every man's hand was against him; and by the doctrine of the survival of the strongest and fittest that pioneer had forced his way westward, westward!

Leaving Babylon we can follow him to the cities of the colony of Assyria-Assur, where the Tigris was crossed.* To Kalah and Nineveh, then both young and dependent on the mother land, so onward he passes until Kharran, the principal resting-place in the upper Mesopotamia, is reached. Here he was among the tribes of the Nahrai, or people of the rivers—a people of whose civilization we know, as yet, but little, but who were always powerful enemies of the kings of Assur. Kharran, Urfa, and the ruins in the Jebel Abdul Aziz, and on the banks of the Khabur, show that this people were no mere confederation of wandering tribes, but were city builders; and recent research in their lands show them to have been the inventors, though perhaps at a late period, of a mode of writing distinct from that of surrounding nations. Kharran, imbued with the influence thus borne to it by this artery of culture, had adopted the Sabean and astrological creed of Babylon, and retained it for centuries after both Nineveh and Babylon had passed away. Indeed, even up to the present time, strange traditions and superstitions, relics of the ancient creed of the people, linger in Kharran. From this ancient city the route passed westward until the Euphrates was reached in the neighborhood of the Hittite city of Carchemish, the emporium of commerce on the river.

Henry Maundrell, one of the earliest English travelers in Syria, who, in 1699, A. D., voyaged from Aleppo to the Euphrates, states that when visiting Jerablis, the site of Carchemish, the natives told him that at or near this point there were traces of an ancient bridge over the river. Of the remains of this ancient means of transit, the traveler states he saw no traces, but the author of this notice, who has recently visited the site, was able to identify the remains which probably gave rise to this idea. About four miles south of Jerablis, on either bank of the river, are to be seen two of the mounds so common in those lands, which evidently mark the sites of ancient ruins. From their position at a point where the river in ordinary seasons would be fordable, it is evident that these mounds mark the site of the forts or towers which guarded the ford over the river where the caravan road crossed.

At Carchemish, this roadway was formed by at least two other caravan routes, one of which followed the west bank of the Euphrates, passing to Babylon; the other, the northern road, which brought down the trade from the districts of the Western Armenia. Of these two roadways, it is not our intention to deal in the present notice, they being better considered in relation to the great Hittite capital.

From Carchemish the Egypto-Assyrian route passed across the plain, to the north of Aleppo, by the cities of Arpad, the site of which is now marked by the mounds of Tel-Erfad, and Khazaz, the modern Azaz. From this point the roadway passed by a narrow ravine through the limestone "Jebel Junneh" into the plain of El-Amk. Hence it passed south through all the cities of the people of Hamath, until at last it emerged by the open pass which divides the northern Lebanon range from the Jebel Ansaria, and emerged on the sea-coast a little to the north of the site of Tripolis. This pass is one of the gates of Northern Syria, and may be identified with "the entry into Hamah." By Arvad and the Phœnician colonies, on the coast, it passed on to the cities of Tyre and Sidon, the homes of the merchant princes of Phœnicia.

It has been necessary thus far to trace the route of this roadway in order the better to understand the historical importance of one of the stations on the route, namely, the rock pass at the mouth of the Nahr-el-Kelb, a pass which was the gateway of Phœnicia. Few

*The ancient name of Assur was "the place of his crossing," or "the city of the ford."

spots in the whole of Syria can rival this rocky pass in historical records or associations, or show so interesting a series of monuments of those whose names are famous on the roll of history.

This historic pass is situated somewhat less than seven miles north of Bierut, at a point where the short but rapid Nahr-el-Kelb, the "Dog River," enters the sea.

The promontory is composed of large honey-combed masses of limestone rock, which are torn and broken into every shape and form by the rude hands of centuries. The gray rocks which wall this roadway being stained in many places by the iron oxide, especially in the places where clefts in the sides have become the channels for small mountain-rills, present a variety of strange tints. Perfectly barren and broken into immense boulders piled one on top of another, like some huge cairn, and stained with the blood red of the oxide, one could not help associating the dull, silent statues, which from the upper ledge of rock looked down on all with a stony calmness, with some mighty conflict which in a by-gone age had raged in this rugged spot.

It was, no doubt, owing to this cairn-like appearance which many of the rocks assumed that Henry Maundrell, in his description of the sculptures in 1697 A. D., suggested them to be possibly the representations of some persons buried there.

Shortly after entering the pass from the south or Bierut end one perceives the statues or sculptured tablets which have rendered the pass of so much interest. They are on the right of the present roadway, and upon a ledge or terrace of the rock which crowns the upper portion of the promontory. The examination of the records has shown that they are arranged in historical sequence, at least as regards those erected by the Assyrian kings; and we may, therefore, consider them in the historical order.

The road by which the pass is traversed is of Roman construction, and passes along a ledge cut out of the face of the cliff and over the sea, its highest point being about 100 feet above the water. This road is now used for the caravans passing by the sea-shore route to Tripolis, Jebeil, and other coast towns. On the upper platform or ledge, which we shall see are the remains of the more ancient roadway, almost directly opposite the highest point of the pass, is the first of the sculptures, a tablet of Assyrian workmanship, and the best preserved of the series. On this same ledge there are also two pairs of tablets, Egyptian and Assyrian, this series of five tablets forming the Southern group.

Following the roadway, we come to the nose or extreme point of the rocky promontory, and here the road takes an abrupt turn east, and passes along the bank of the Nahr-el-Kelb. The descent here is steep and slippery until the ford is reached. Twenty yards down this roadway, and facing the traveler, is a finely-sculptured Assyrian tablet, which is placed to the right of the roadway, on the rock which forms the corner stone between the ancient Assyrian road and the Roman road. From this point to the ford the most ancient Assyrian road and the Roman road coincide. Between twenty and thirty yards further along this roadway, a second pair of Assyrian tablets are to be found cut on the rock, and directly opposite the ford there is an Egyptian tablet, The Roman road is continued for about 600 yards further up the pass, and crosses the river by a bridge.

An examination of these records shows that, as regards the Assyrian tablets, they are arranged in an historical order commencing with the pair of tablets near the ford (Nos. 2, 3), and terminating with that which crowns the highest point of the pass (No. 9).

The table on next page will show this order, together with the epochs to which the sculptures may be assigned.

The first tablet is an Egyptian work, but, unfortunately, it is quite destroyed, having been taken by the French troops forming the army of occupation in 1860–1, during the time of the Druze massacres, to receive an inscription recording their presence. The preparation of the surface necessary for the reception of the new inscription has entirely removed all traces of the ancient inscription. Dr. Lepsius, the German Egyptologist, however, made an examination of the record in 1845, prior to the mutilation, and was then able to trace sufficient inscription to identify it as the

No.	Nation.	Shape.	Date and Remarks.
1	Egyptian........	Square[1]................	Rameses II. Dedicated to Phtha.[2]
2	Assyrian.........	Square..................	Assur-ris-ilim (B. C. 1140).[3]
3	"	"	Tiglath-pilieser I. (B. C. 1120).
4	"	Round-head...........	Assurnazirpal (B. C. 885).
5	"	"	Shalmanesar III. (B. C. 860).
6	Egyptian.......	Square	Rameses II. Dedicated to Ra.[2]
7	Assyrian.........	Round-head............	Sennacherib (B. C. 702).
8	Egyptian........	Square..	Rameses II. Dedicated to Ammon.[2]
9	Assyrian.........	Round-head...........	Esarhaddon (B. C. 681).[4]

[1] The surface of this tablet has been planed and a French inscription cut upon it.
[2] These dedications are assigned by Dr. Lepsius, of Berlin, who examined the tablets in 1845 ("Briefe aus Egypten," 402).
[3] Much worn.
[4] Portion of inscription proves erection in B. C. 672–1.

work of Rameses II., the great Sesostris, and to attribute it as an *ex voto* to the all-wise Phtha. The monuments have also been examined by the late Joseph Bonomi,* and he also attributes them to Rameses. "The most ancient, but unfortunately the most corroded, are three Egyptian tablets; on them may be traced the name of Rameses,† to which period any connoisseur of Egyptian art would have attributed them, if even the evidence of name had been wanting, from the beautiful proportion of the tablet and its cavetto moulding." These Egyptian tablets, Nos. 1, 6, 8, are all similar in shape, being 7 ft. 6 in. high and 3 ft. 8 in. in width at the top, and somewhat more at the bottom. They are surmounted by the overhanging cornice with cavetto moulding, and a feather decoration on the cornice. Upon the lintel of the framework is the winged circle, or solar disc, and the nomens and prenomens of the monarch are inscribed on the jambs. Egyptian records show that these tablets were placed here by the great conqueror, Rameses II., as *ex votos* for his victories over the Kheta and other Syrian allies. The two earlier ones, Nos. 1, 6, which are dedicated to Phtha, and the solar deity Ra, were erected for victories over the Rutennu;‡ but the last one, dedicated to the deity Ammon, is to commemorate the personal triumph of Rameses over the "vile Kheta" and their allies. The tribes of the Kheta or Hittites, the people of Kair Kamasha (Carchemish), of Charibu or Chalibu (Khelbon), or Aleppo, and the southern Hittites, afterwards the Hamathites, the people of Kadesh, had all gathered against the great conqueror. By a great battle before Kadesh, on the Orontes, the allies were defeated and made peace. In this battle the royal commander performed most valiant and superhuman deeds, and the account of his mighty acts are set forth by the poet laureate of that period, one Pentaur or Pindar, the royal scribe, in a long heroic poem.*

We pass now to consider the Assyrian records in this series. First, we have a pair of square-shaped tablets, Nos. 2 and 3, placed side by side about thirty yards above the ford. They represent two royal personages clad in the robes of royalty. The workmanship is evidently that of an early period of Assyrian art, and much earlier than the other sculptures. The reliefs of figures are low and squat in shape, and lack that stately proportion and dignity which we find in the works of either the middle or later empire. There is none of that attention to minute details of features or dress which mark the best Assyrian art. It is, therefore, clear that these works were of a style of art prior to the ninth century before the Christian era. If we examine them closely we find a resemblance in tone to works of which we know the date. There is in the British Museum (Assyrian side room) a statue of an early Babylonian king, Merodach-Nadin-Akhi, who reigned in the twelfth century before the Christian era. The first pair of Assyrian sculptures of which we are

* Transactions R. Soc. Lit., art. iv., by Joseph Bonomi, vol. iii., p. 105, 1839.
† Rameses II.
‡ Or tribes dwelling in the lands forming the basin of the Litany river.

* Third Sattier Papyrus, in the British Museum.

speaking exhibit a marked resemblance to this and other early works,* and we may, therefore, assign these records to the period of the Early Assyrian Empire; that is, the twelfth century before the Christian era. Of the monarchs whose reigns are included in the period of the Early Assyrian Empire, there are two who made expeditions into Syria and penetrated as far as the "sea of the setting sun," namely Assur-Ris-Ilim, B. C. 1140, and his son, Tiglath-Pilieser I., B. C. 1120, a monarch whose reign formed the zenith period of the Early Assyrian Empire.

Of the former of these monarchs we have no lengthy inscription, and his only claim to be considered the monarch who erected one of these statues is his adopting in his inscriptions the title, "the conqueror of the land, as far as the sea of the setting sun." His son, the warlike Prince Tiglath-Pilieser I., has, however, left us a record of his campaigns in the regions of Western Syria, and of his visit to the cedar woods of Lebanon.

In the latter part of his reign, this monarch, having subdued all the tribes of the Nairi, or Upper Euphrates valley, turned his arms against the warlike tribes on the west bank of that river. He crossed the Euphrates, and took the city of Pitru or Pethor, the birth place of Balaam, which was situated at the mouth of the Sadjur; he then advanced against Carchemish, some twenty miles north, and after reducing that city he marched southwest to visit the Lebanon, to obtain cedar, for the decoration of his palaces and temples. He advanced as far south as Arvad or Ardus, where he entered into a ship and slew with his own hand a porpoise.† It is probable that, during this or a subsequent expedition, he visited the cities of Phœnicia, and then erected his statue on this gateway of Phœnicia. Had he been in the neighborhood, as he was when he visited the regions of the cedar groves, and possibly Afka or Apheca, the sacred glen of Astarte, he must have heard of the records of the Egyptian conqueror which were upon the rocks over against the great sea, and his arrogance and pride would prompt him to go and erect similar records of his greatness.

We now move some thirty yards up the pass to the point where the ancient roadway joins the present or Roman road, and on the corner rock here we find another finely cut Assyrian memorial tablet. It is cut on the surface of the rock facing the sea, and is about 7 feet above the roadway. The preparation of the rock, and the work of the tablet itself, at once show it to be the work of a period more advanced in art than that of the tablets below it. It is 6 ft. in height and $2\frac{1}{2}$ ft. in breadth, and the depth of the niche is about 5 in. These Assyrian tablets are cut somewhat deeper at the top, in order that the water which drips down the face of the rock may be carried clear of the upper portion of the sculpture.

The resemblance which this memorial record presents to well known Assyrian monuments enables us very clearly to ascertain the period when it was executed. It may be compared with such monuments as the stelæ from the temple of the war god at Kalakh, or Nimrud, which may be seen in the British Museum. These stelæ were erected by kings of the middle Assyrian empire. In the Assyrian vestibule of the British Museum we have a finely preserved monument of this class, which was erected in the temple of the war god at Kalakh (Nimrud), and which in sculpture is an exact counterpart of the bas-relief now under consideration. This monument was erected by Assurnazirpal, B. C. 885, one of the great monarchs of the middle Assyrian empire. In the side room we have also a similar class of monument erected by Samsi-Rimmon, the grandson of this monarch. The memorial tablets from Kurkh, near Diarbeker, on the Tigris, now in the British Museum, are also of the same class, as well as the rock sculptures at the sources of the Tigris, the headwaters of the Debeneh-Su.

This tablet No. 4 evidently pairs No. 5, which is situated on the higher ledge of rock about 150 yards distant, and we may therefore assign them to the same period. In the case of these two interesting monuments, the historical records, which have been rescued from the graves of Ninevah and other Assyrian towns,

* *Bas-relief* of a king in grey granite in the same room, and the rock sculptures on the Debeneh-Su, near Diarbeker.

† The animal is called the *nakhari*, "blowing animal," and is probably the porpoise.

afford us much interesting information, and enable us to fix the period of their erection. The lower of the two we may certainly assign to the great conqueror Assurnazirpal, B. C. 885, who subjugated the whole of Western Asia to the Assyrian rule.

From the great historical inscription which covers the pavement slabs of the rich war temple at Kalakh, we learn the details of the campaign which this statue commemorates. "On the 8th day of the month Iyar [April]" probably in the year B. C. 870, the Assyrian monarch started from the royal city of Kalakh on an expedition, the ostensible object of which was the subjugation of the Hittite power and the capture of Carchemish. After following the ancient military road, the route of which we have traced, he came to Carchemish, the king of which submitted. His intention now was to proceed to the Lebanon to cut cedar for his extensive building works at Nineveh, and to extort some tribute from the rich Phœnicians.

"In these days I occupied the sides of the mountains of Lebanon (Labnana).
To the great sea of the west I approached.
My arms upon the great sea flashed.
To the gods I sacrificed, and tribute of the princes of the sea shore of the lands of Tyre, Sidon, Gebal [Jebeil], Makullat, Mázai, and Kaizai of the Phoenicians of Arvad, in the midst of the sea I received."

This tribute, we are told, consisted of all the wealth of Phœnicia. The king then speaks of the cutting of cedars in Lebanon; and it was evidently during his campaign that his statue was erected over against the great sea. We may, therefore, safely assign this tablet to the great king Assurnazirpal, whose statue from Nimrud it so closely resembles. Before proceeding to describe this pair of statues, we will notice the historical data with regard to the erection of the second of the pair—namely, that which is on the platform of rock above the present roadway.

This statue we may certainly attribute to Shalmanesar III., the son of Assurnazirpal. This monarch came to the throne of Assyria in B. C. 860, and at once commenced to carry on the warlike policy of his father. In his first year, B. C. 859, he marched forth on a tribute gathering expedition, and after visiting the cities on the banks of the Khabour, Carchemish, and of Hittite cities, he came to the cities of the sea coast.

"[To] The upper cities of the west and the sea of the setting sun. . . . .
The tribute of the kings of the sea coast I received on the shores of the broad sea. . . . .
I descended. An image of my lordship. The record of my name for ages I made. Over against the sea I placed it."

Such is the record of the erection of this royal statue, which was to be a record of the king's name. Little did he think that for over twenty-seven centuries it would stand as a record of the deeds which he had done.

The king is clad in the long sleeveless robe, or "kamis," richly embroidered and fringed, and on his head is the royal tiara, or cap. These caps may to this day be seen worn by the Kurdish chieftains, but now made of a species of felt; whereas at that period the material was probably of metal-work. The right hand is extended in adoration towards sacred symbols which occupy the corner of the background.

These Assyrian memorial tablets differ materially from those of other nations, yet they have contributed much to the adoption of this kind of memorial by the Hittites, Lydians, and other nations.

That wonderful brazen war panorama which has been restored to us in the bronze gates from Ballawat has brought before us an interesting tableau connected with these memorial stelæ. We have there the representation of the erection of one of these memorial tablets upon the rocks over against "the great sea of the rising sun," the sea of the Nairi, that is Lake Van. In that scene we have before us the ceremonial which took place, and we see how important was the event considered to be, how royal pomp and religious ceremony were all brought to bear upon the work and to contribute to the glory and honor of the great king. Priests with portable altars are standing before the statue and burning incense, and victims are being brought forward to be slain. The soldiers or attendants are seen casting portions of a victim already offered into the sea, to propitiate the gods of the deep. On the occasion of the erection of one of these royal *ex votos*, not only were offerings made to the newly erected sculpture, but also to those which had

preceded it, so as to pacify and honor the manes of the ancestors of the king.

This last tablet, No. 5, the monument of Shalmanesar III., has been erected alongside of an Egyptian one. The late Mr. Bonomi suggested that the Assyrians had availed themselves of the surface of the rock which had been prepared by the Egyptians. This may be possible; but there also seemed to be a special motive in the juxtaposition. We find Nos. 5, 6, placed side by side, and Nos. 8, 9. No. 5 was, as we have seen, the work of Shalmanesar III., and No. 9 that of Esarhaddon, both of which monarchs in their wars had come in contact with the hostility of Egypt. The former had only, at the time at which his statue was erected, been opposed to the intrigues of Egypt among the Hittites, but the latter had come into actual and victorious conflict with the serpent of Old Nile, and had erected his tablet here to commemorate victory. It is, therefore, more probable that the juxtaposition is the result of this feeling of arrogance towards Egypt.

The two Egyptian tablets in this upper road have been at some time protected by bronze doorways, in a similar manner to the trypticles in churches, and the holes in which the sockets of the hinges were inserted are yet to be seen.

The tablet No. 7, which is placed a few yards further up the cliff, south of the Egypto-Assyrian group (Nos. 5 and 6), has, by nearly all who have examined it, been assigned to Sennacherib (B. C. 705). The examination of this sculpture shows that we have now a work of a more advanced art period than that which we meet with in either of the other tablets. The framework which encloses the sculpture is larger and better proportioned, the sizes being 7 ft. 3 in. high, and 3 ft. 8 in. wide. The workmanship shows it to belong to the best period of Assyrian art, and although there is no record of its erection by Sennacherib to be found in the inscriptions, its resemblance to the Bavian and other records of that king show it to be a work of his reign. Sennacherib visited Syria and Palestine at least three times in his reign. In B. C. 703-2, he defeated the Palestine and Egyptian armies at Eltekeh, an eccount of which expedition is found in the Taylor cylinder. There were probably at least two other expeditions against Palestine later in his reign, as shown by the fragmentary records in the British Museum.

In this text of the Taylor cylinder there is no mention made of the erection of a royal statue on the shores of the great sea, but this does not preclude the possibility of such an event. In the inscriptions of Sennacherib and his successors a more florid style of literature is in vogue than in the time of Shalmanesar and the kings of the Middle Empire. The former style was a diurnal one; each halt, each river crossed, and almost every event of the march, with most accurate statistics of the tribute, &c., are given, but in the texts of the time of Sennacherib a more grandiloquent and general style is adopted, and these minute details are omitted. The increase of bureaucracy had formed a style which left these details to the terra-cotta despatches and blue books in the War or Record offices of Nineveh, while gilded and verbose abstract was given on the record cylinders of the king.

The last group of these interesting monuments of antiquity consists of a pair of tablets, one Egyptian and the other Assyrian. The first of these, No. 8, is dedicated to the Theban Ammon, and was erected in honor of that deity by Rameses II., after his great victory over the Kheta and their allies; the second is an Assyrian tablet, similar in style to the three last described. This monument is the one of which Henry Maundrell, who visited the pass in 1697 A. D., states "there is one of the figures that had its lineaments and inscriptions entire. A cast of this sculpture was obtained by Mr. Joseph Bonomi in 1834, and was presented to the British Museum by the Duke of Northumberland."*

In the possession of this copy the British Museum authorities are fortunate, for they now have in it a much better copy than the original monument. Forty-five years of exposure to the wear of the sea and air have obliterated much that was visible, and one failed to recognize portions of the inscription which are known to be extant in the cast. In the upper left-hand corner of

* It is in the Koyunjik Gallery.

the tablets are a group of sacred emblems, the sun, crescent moon, the seven stars, or pleiades, and other religious emblems. The royal features, hair, beard, and headdress, the portion of the robe not obliterated by exposure, all show the greatest attention to detail, and the sculpture when perfect must have been a fine example of Assyrian workmanship. Some of the remaining portions exhibit an amount of fine carving rarely expended on rock sculptures, which are usually bold in outline and scant in detail. Strange to say, in direct opposition to all this extra attention to workmanship on the part of the Assyrian artist, the selection of the portion of rock exhibits a most decided mal-judgment. A portion of rock has been chosen which is covered with a thin superficial layer of fine stone. The cutting of the *bas-relief* and inscription has worn this extremely thin; the result is that in exposed portions the layer has disappeared, taking with it large portions of sculpture and text.

The sculpture represents the king standing arrayed in royal robes, and wearing the royal tiara, or headdress, richly decorated with floriated rosettes. The right hand is elevated towards the sacred emblems, and the king appears to hold in his hand a couple of feathers. We now turn to the fragmentary inscription which covers this interesting record to see what royal and kingly personage is here represented. The occurrence of such names as Assur-akhi-iddira, Esarhaddon, Sin-akhi-irba, Saincherib, together with the royal titles of "King of Babylon," "King of the Lands of Egypt and Ethiopia," and the mention of an expedition against Tarq or Tirhakah, ending in the sack of "Memphis, his royal city," furnish sufficient detail to enable us to form an accurate conception of the date of the tablet.

By these titles and data we may see that the statue represents Esarhaddon, the third and faithful son of Sennacherib, who came to the throne of his father in B. C. 681, and reigned until B. C. 668, when his son, Assurbanipal succeeded him.

Ever since the rise of the Ethiopian or twenty-sixth dynasty in Egypt, there had been a rapidly increasing opposition between the two great powers of the East. Sargon had come in contact with the king (Siltan) of Egypt; Sennacherib had suppressed the revolt in Palestine due to the intrigues of Tirhakah; and now again, in the reign of Esarhaddon, the messengers of Egypt were raising revolt in the lands on the borders of the Western Sea. From a small inscription, now in the British Museum, we learn that in his tenth year (B. C. 672.1)* Esarhaddon had news of a revolt in Tyre. In the early part of his reign the intrigues of Egypt at the court of Sidon had led to its destruction by the Assyrians, and now Tyre, who had benefitted by the fall of her sister city, was yielding to the flattering solicitations of Egypt.†

By the defection of Tyre the Egyptian king had hoped to cause a block on the Assyrio-Egyptian road, and thus give time for a more effective resistance in Egypt. Esarhaddon, however, lost no time, but marched direct across the Syrian desert, probably by the Damascus caravan route, and entering Palestine near the city of Aphek (*Apku*), on the borders of Samaria, he despatched one contingent of his army to hold in check Tyre, with the other he marched direct into the heart of Egypt. This well planned campaign ended in the defeat and flight of Tirhakah and the capture of Memphis and many other Egyptian cities. Egypt was divided into twenty-two satrapies under governors dependent on the court of Assyria, and the Assyrian king returned with an immense booty. On the return march, which followed the Assyrio-Egyptian road, tribute was gathered from the principal Palestine and Phœnician cities, and also from the kings of Cyprus.

It is an interesting fact that the inscription at *Nahr-el-kelb* commences with an enumeration of the titles of Hea or Oannes, the god of the sea, which seems to indicate that this is an *ex voto* for a successful sea voyage. It is possible that the Assyrian king had prepared to bring the rich spoils of the Egyptian campaigns and the tribute of Tyre and other cities in ships taken from Egypt

* Transl. by W. St. C. Boscawen, Trans. Soc. Bib. Arch., vol. iv., pp. 84-97.

† On the fall of Sidon, a convention granted by the Assyrian king had ceded Dor Accho (Acre) and Gebel (Jebeil) to Baal, King of Tyre, the pass of the Nahr-el-Kelb would therefore be at that time in the Phœnician hands.

rather than by the difficult overland route.

From these facts we may conclude that this statue was erected in B. C. 670, to commemorate the successful termination of the war in Syria and Egypt. With this statue of the conqueror of Memphis ends this historic sculpture gallery.

By a strange chance coincidence this last record is placed by the side of an Egyptian tablet, recording the victories of one of the greatest of the Pharaohs. With Egypt in its glory it begins; with fallen and crushed Egypt and captured Memphis it ends. How plainly now do we see in the small act of thus placing his statue close alongside the Egyptian's record, the proud assertion of the victor's power.

"O Heaven, that one might read the book of fate,
And see the revolution of the times!"

Rome has left here a record in this pass to tell of her dominion, as near the bridge may be seen a rock-cut tablet bearing an inscription of Marcus Antoninus (A. D. 179), who made the lower or Roman road.

Last in the series of records of great men and mighty deeds we have an Arabic inscription of Sultan Selim I. (A. D. 1517), who repaired the bridge which crosses the stream.

Thus, in this rocky pass, under the slopes of cedar-famed Lebanon, there are preserved the records of the conquerors of the East for more than thirty centuries,* and by their aid we can form some idea of the grand armies which have in the past trodden this most ancient of roadways.

* This includes the French occupation in 1860. The records extend from 1350 B. C. to 1860 A. D.

IRON AND STEEL AT LOW TEMPERATURES

By JOHN JAMES WEBSTER, Assoc. M. Inst. C. E.

From the Proceedings of the Institution of Civil Engineers.

I.

From the earliest days of iron-bridge building, some forty years ago, to the present time, the opinion of engineers as to the condition of iron and steel at temperatures below the freezing point of water has been much divided. The general impression appears to be that both materials are, to a certain extent, affected when subjected to the action of frost, by becoming more crystalline in their structure, thus making them incapable of bearing the same strains they could sustain at a higher temperature. This impression has probably arisen from the fact of so many rails, tires, axles, chains, &c., having broken during severe winters. If, however, the returns issued by the Board of Trade be examined, it will be found that the majority of recorded fractures do not occur in winter; and even if they did, it has been often and justly held, that the fractures may have occurred not from the action of frost on the materials, but from other causes, such as the rigidity of the frozen road, restrained contraction of the materials, formation of ice in crevices, &c. On the other hand, it must be remembered, that in those countries where the winters are longer and more severe than in Great Britain, no such records of fractures are kept, or possibly it might be found that they occurred more frequently in winter than in summer. Again, some of the fractures which are now recorded as having occurred at ordinary temperatures, may possibly have had their origin during a severe frost, and after the materials had withstood the working strain for some time, may finally have given way during perhaps one of the hottest months in the year, thus showing the impossibility of forming any opinion of value on what is merely circumstantial evidence.

Many eminent engineers gave a large amount of evidence on this subject before "the Commissioners appointed to inquire into the Application of Iron to Railway Structures," and all were of opinion that both wrought iron and cast iron were weaker when at temperatures

at or below the freezing point. The evidence on this head was, however, nearly all founded on opinion, and not from direct experiments. The principal experiments mentioned were those of the late Sir William Fairbairn, and of Mr. Brunel. The latter, when giving evidence of the possible change of structure of iron from continued vibrations, said, "I should mention that I have tried temperature also, freezing mixtures and warmth, and that the difference is decided; the iron in a cold state breaks shorter and shows more crystalline fracture than the same iron warmed a little; and, I have no doubt, you might take a bar 10 feet long and break it into ten pieces, and make them all in turn crystalline and fibrous according to the temperature." A little further on in his evidence he says, "I would just wish to say, in reference to an answer which I gave to a former question, that I believe that cast as well as wrought iron varies in its strength with the temperature." No detail of the experiments referred to were put in evidence, and the author has not been able to find any record of them.

Since that time numerous experiments have been made to ascertain, if possible, the real condition of iron and steel at low temperatures, but with no satisfactory results; for if the results were summarized, such a mass of contradictory evidence would be found, that the question would appear almost as far off solution as ever.

Many of the experiments have been of the crudest form, and need not be considered, although it is astonishing what strong opinions have been formed and expressed by some engineers on no stronger evidence for the foundation of their belief than perhaps the breaking of a few bars of iron with a sledge hammer in winter, or other trials equally rough and valueless. The most important experiments on the subject, are those of the late Sir William Fairbairn, M. Knut Styffe, and Mr. C. P. Sandberg, Assoc. M. Inst. C. E., and as the results obtained by them give important evidence on the question, it is proposed briefly to consider them.

EXPERIMENTS BY SIR WILLIAM FAIRBAIRN.

The first series of experiments by Sir William Fairbairn were those made upon cast iron only, and they formed part of his evidence before the Commissioners. The experiments were made to ascertain the transverse strength of bars 1 inch square when placed on bearings 4 feet 6 inches apart; two bars being tested at a temperature of 26° Fahrenheit, four bars at 32°, two bars at 190°, and two bars at 600° Fahrenheit. As one-half of the bars were of cold blast iron, and the other half really of hot blast iron, the experiments were reduced to a comparative test of three bars at the low temperatures, and one bar at the higher temperature.

The next trials, given in the same evidence, were made to ascertain the resistance of cast iron bars to impact, and were under precisely the same conditions as the above, as far as regards the temperatures and number of bars tested. The summary of his evidence on these points were as follows: "On the whole, we may infer that cast iron of average quality, loses strength when heated beyond a mean temperature of 220°, and it becomes insecure at the freezing point, or under 32° Fahrenheit."

The next series of recorded experiments by Sir William Fairbairn are those in a paper read by him before the British Association in 1856. In this instance, wrought iron plates and bars were tested, and in the summary of results obtained at the different temperatures, one plate and one bar only are given as being tested at 0° Fahrenheit, and six plates and three bars at temperatures rising from 60° to 435° Fahrenheit. The test strips were broken horizontally in a single lever machine, having a scale pan at one end of the lever, but without any of the fine adjustments which are fitted to the machines of the present day. The results led him to believe "that iron bars or plates were not materially affected by cold." These experiments were evidently carried out more with the intention of ascertaining the strength of iron at high than at low temperatures, and, although they were conducted and recorded as accurately as possible with the then existing apparatus, the author is of opinion that the experiments on both cast and wrought iron were of far too limited a character to justify any definite conclusions being drawn as to the real condition of iron at low temperatures.

EXPERIMENTS BY M. KNUT STYFFE.

By far the most elaborate and carefully conducted experiments upon iron and steel at low temperatures are those by M. Knut Styffe, Director of the Royal Technological Institute at Stockholm. Of these a full account, with the results and conclusions arrived at, is published in a book which has been translated by Mr. C. P. Sandberg, Assoc. M. Inst. C. E.

The experiments were carried out in 1865, for the information of the Swedish Government Committee appointed to report upon the relative value of steel and iron in the manufacture of railway materials. The materials experimented on included a large number of samples of Swedish iron and steel, Krupp's steel, Lowmoor, Cleveland, and Welsh iron, and some bar iron from the Earl of Dudley's works. The principal object of M. Styffe's researches was to establish the exact limit of elasticity of each sample, considering this to be the true measure of its strength; but a large number of the tests were made to ascertain the tensile strength of iron and steel at very low temperatures. M. Styffe came to the following conclusions:

1. "That the absolute strength of iron and steel is not diminished by cold, but that even at the lowest temperature which ever occurs in Sweden, it is at least as great as at the ordinary temperature (about 60° Fahr.)."

2. "That at temperatures between 212° and 392° Fahr., the absolute strength of steel is nearly the same as at the ordinary temperature; but in soft iron it is always greater."

3. "That neither in steel nor in iron is the extensibility less in severe cold than at the ordinary temperature; but that from 266° to 320° Fahr. it is generally diminished, not to any great extent, indeed, in steel, but considerably in iron."

4. "That the limit of elasticity in both steel and iron lies higher in severe cold; but that at about 284° Fahr. it is lower, at least in iron, than at the ordinary temperature."

5. "That the modulus of elasticity in both steel and iron is increased on reduction of temperature, and diminished on elevation of temperature; but that these variations never exceed 0.05 per cent. for a change of temperature of 1°.8 Fahr., and therefore such variations, at least for ordinary purposes, are of no special importance."

These results are contrary to generally received opinions, showing that, if anything, iron and steel are actually stronger at low temperatures. The experiments were conducted most carefully, and the results recorded very minutely, but one or two points are, perhaps, open to discussion. For instance, the sectional areas and extensions are given to $\frac{1}{10000}$ inch, and although an accurate measuring rod, regulated by fine micrometer screws, was used, yet, in direct measurements, no matter how delicate the apparatus, there is always a liability of errors, and it is only by such a device as that adopted by Professor Kennedy, in his testing apparatus at University College, that such measurements can be relied upon. The sections are stated to have been obtained with callipers, but even supposing they were vernier callipers, it seems doubtful if such minute measurements could be taken to four places of decimals.

The bars were about $\frac{1}{2}$ inch round or square, and were filed down to about $\frac{1}{8}$ inch square for a length of from 4 to 6 inches in the center. It is to be regretted that the portion of the bar under the actual test was of so small a sectional area, as no doubt, when such small sections are used, errors are liable to occur; for supposing the bars to have been filed to such a nicety, if they were not perfectly homogeneous—a most probable condition—the percentage of error would be far greater than if the bars had been of larger section. This error would have been reduced had more samples of the same class of iron been tested; but the tables show that, although nine bars of iron and six bars of steel were tested at the low temperatures, in no case were more than two of the same quality of iron or steel experimented upon, the same number of bars being tested at the high temperatures to make the comparison.

The next most interesting series of experiments on this subject are those by Mr. C. P. Sandberg, which may be briefly described as follows:

EXPERIMENTS BY MR. C. P. SANDBERG.

Mr. Sandberg was of opinion that, although the experiments of M. Styffe might prove that iron and steel at low temperatures were not reduced in tensile strength, yet when subjected to sudden blows or shocks, they might possibly be affected by the action of severe frosts; and in order to ascertain this point, he made a large number of experiments which are fully described in the appendix of his translation of M. Styffe's work.

These experiments were made in Sweden in 1867, with seven iron rails from Aberdare, five rails from De Creusot, and two Belgian rails. The rails were all 21 feet long, and were broken by being placed on two granite blocks 4 feet apart, resting on a solid granite foundation, and allowing a ball weighing 9 cwt. to fall upon the rail between the points of support from varying heights. The two broken portions were afterwards tested in a similar manner; the tests were made at temperatures of 10°, 35°, and 84° Fahr.

From the results of his experiments, Mr. Sandberg came to the following conclusions, viz.:

1. "That for such iron as is usually employed for rails in the three principal rail making countries (Wales, France, and Belgium), the breaking strain, as tested by sudden blows or shocks, is considerably influenced by cold; such iron exhibiting at 10° Fahr. only from one-third to one-fourth of the strength which it posssesses at 84° Fahr."

2. "That the ductility and flexibility of such iron is also much affected by cold, rails broken at 10° Fahr. showing on an average a permanent deflection of less than 1 inch; whilst the other halves of the same rails, broken at 84° Fahr., showed a set of more than 4 inches before fracture."

3. "That at summer heat the strength of the Aberdare rails was 20 per cent. greater than that of the Creusot rails; but that in winter the latter were 30 per cent. stronger than the former."

There can be no doubt of the accuracy of the results of these experiments. Is it equally certain that the decrease of strength recorded was entirely due to the action of the frost? The author is of opinion that it is not, and for the following reasons:

It must be noticed that nearly all the bars tested at the lower temperature were the 21-feet lengths, and those tested at the high temperature the short lengths; but if the bars had been all of the same length, different results would most probably have been obtained. The experiments made by Mr. Hodgkinson for the Royal Commissioners, proved conclusively that in the case of a bar subjected to impact, the strength did not increase with the reduction of the distance between the points of support, as in the case of a statical load, but that the strength actually decreased, the force evidently being taken up in bending the bar, and in overcoming its inertia. This conclusion is given as follows in the Report of the Commissioners:

"The experiments in Tables I., II., III., IV., V. afford illustrations of some of the conclusions in the large generalization of Dr. Young, deduced from neglecting the inertia of the beam (Nat. Phil., Lecture XIII.). 'The resilience of a prismatic beam, resisting a transverse impulse, follows a law very different from that which determines its strength, for it is simply proportional to the bulk or weight of the beam, whether it be shorter or longer, narrower or wider, shallower or deeper, solid or hollow. Thus, a beam 10 feet long will support but half the pressure without breaking, as a beam of the same breadth and depth only 5 feet in length will support; but it will bear the impulse of a double weight striking against it with a given volocity, and will require that a given body should fall from a double height in order to break it.'"

In Mr. Sandberg's experiments, the bearings were 4 feet apart in every instance, but the great overhang at each end, when a long rail was being broken, converted it into a continuous girder, thus virtually reducing this distance. Taking these things into consideration, it would appear that the differences observed in his results were, to a great extent, owing to the differences in the length of the rails.

It will thus be seen how fractures of rails in a permanent way are more likely to occur in severe winters than in the warmer months, the unyielding nature of the ground reducing the actual bearing of the rails to the conditions of a beam

fixed at both ends, and having a span equal to the distance between the chairs, instead of having, as under ordinary circumstances, a much longer span, varying, of course, with the nature of the ground upon which they are laid.

Having briefly reviewed the results obtained, and the conclusions arrived at by different authorities, the author ventures to submit a number of experiments he has made, as a contribution towards the solution of this question.

EXPERIMENTS BY THE AUTHOR.

The materials tested in these experiments were wrought iron, cast iron, Bessemer steel, and best cast steel, as well as malleable cast iron, now extensively used for pitch chains, double links of dredgers, and other important purposes where wrought iron and steel were formerly employed.

As the results are intended merely to show the comparative strength of the materials when at ordinary temperatures, and when under the action of severe frost, the numbers recorded must not be taken to represent the actual strength of any particular class of iron or steel; for the quality of the material was not of so much importance in the experiments as the fact of having all the bars in one set as nearly alike in every way as possible, although in many instances high results were obtained. In the first experiments the comparative tensile strengths of wrought iron, malleable cast iron, and Bessemer steel, were observed when at ordinary and at low temperatures, twelve bars of each being tested, six each at 50°, and six each at 5° Fahrenheit, the latter temperature being considered a fair representation of the severest frost likely to be experienced in this country.

The experiments were made to ascertain the comparative transverse strength of twelve bars of cast iron, six being tested at 50°, and six at 5° Fahrenheit. Cast iron was the only material experimented upon for transverse strains, as it is almost impossible to test wrought iron or steel in this manner, owing to the great deflection of the bars before fracture; it is only in the common material that fracture will take place.

The succeeding experiments were with a view to observe the comparative effects of impact on bars of wrought iron, malleable cast iron, ordinary cast iron, and cast steel, twelve bars of each material being tested, six of each at 50°, and six of each at 5° Fahrenheit.

In all cases, the greatest care was taken to obtain each set as nearly alike as possible. The samples of wrought iron or of steel bars in each set were cut from the same bar, or two bars, rolled at the same time. When the samples were taken from two bars, to reduce any error which might possibly arise from one bar not being exactly the same as the other, three samples of each were tested at the low temperature, and three of each at the ordinary temperature.

The cast iron test bars were all run from the same ladle, a large one being used for the purpose, that there might be an excess of metal after the operation of casting. The malleable samples were cast together, and annealed in the same oven.

All the bars tested at the low temperature were buried in snow for two or three days. Previous to being tested they were covered for about three hours with a freezing mixture of snow and salt, and were then taken direct from this mixture to the machine. While the test was being made they were kept surrounded with the mixture by being placed in a specially constructed box (Figs. 7 and 8).

DESCRIPTION OF THE TESTING APPARATUS.

The apparatus employed for determining the tensile and transverse strains of the different samples, was the testing machine* belonging to the Hull Dock Company, kindly placed at the author's disposal by the courtesy of their Engineer, Mr. R. A. Marillier, M. Inst. C. E.

This machine consists of a series of compound levers, the straining power being applied by a small hydraulic pump. The general arrangement of the apparatus is shown on Plate 7, Fig. 1 being the side elevation. H is the hand pump which forces oil from the tank B into the cylinder C, acting on the top side of the piston, fitted with cup-leathers, and having a jaw forged on the piston-rod head, through which passes the pin D.

* The testing machine was constructed by Messrs. Bell, Lightfoot & Co., Walker Engine Works, Newcastle-upon-Tyne.

The test bar E is held at the bottom by this pin, another pin F passing through the bar at the top, and connecting it to the two links G, which are hung on knife edges fixed to the lever H, coupled by the links J to the top lever K. To

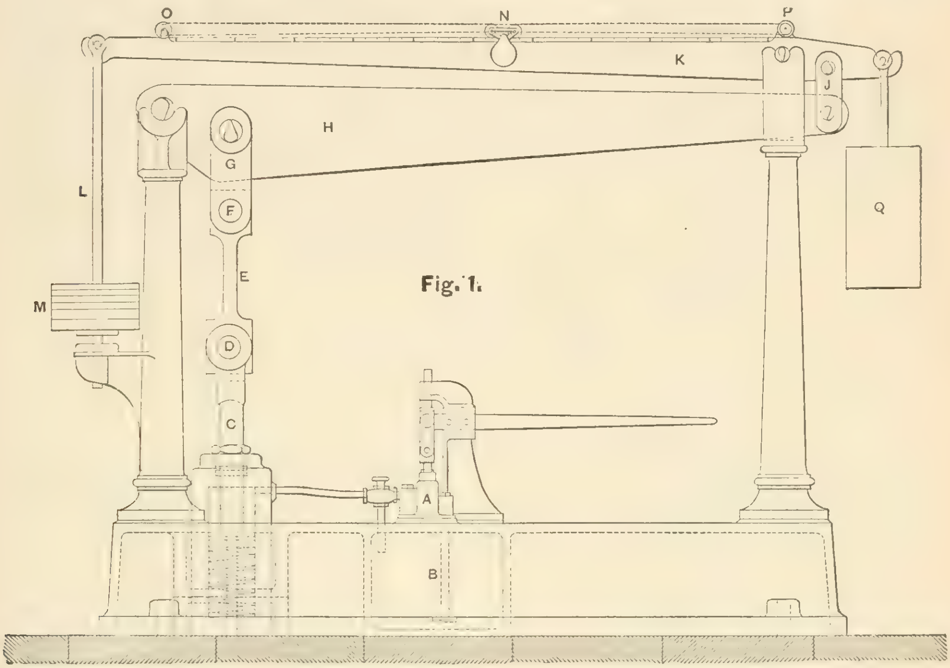


Fig. 1.

this lever is hung the rod L, on which are placed the weights M, for ascertaining, the test loads; the total leverage being 160 to 1. The top edge of the lever K is graduated up to 1 ton, and is fitted with a riding weight N, which is

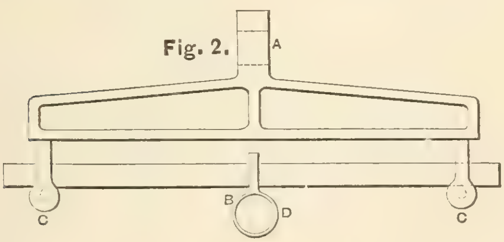


Fig. 2.

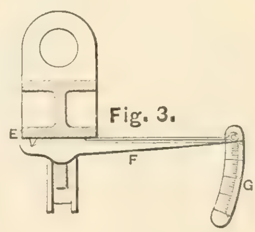


Fig. 3.

moved along by a cord passing over the fixed pulley O, and a small hand wheel and pulley P. The weight of the levers is counterbalanced by the weights Q, and, as all the connections are made by knife edges, the friction is reduced to a minimum, a trifling weight being sufficient to turn the balance. A spiral spring below the piston forces it back into position after a bar is broken. This plan works satisfactorily, the only disadvantage being the increase of pressure in the cylinder, necessary to compress the spring, which varies with the extension of the test bar.

When tests are made with transverse strains, the cast iron crosshead A, Figs. 2 and 3, is suspended from the lever H, the test bar B being placed on the knife edges C; a clip D, with an internal knife edge, rests on the center of the bar, and is attached to the cross head of the piston by the pin D, the pressure being then applied by the hand pump as

before. A small stud E, having its end filed to a knife edge, is screwed into the crosshead A; and against this, on the top edge of the test bars rests a light rod E, used as an indicator of the deflection; the real amount of this being multiplied ten times, and read off on the

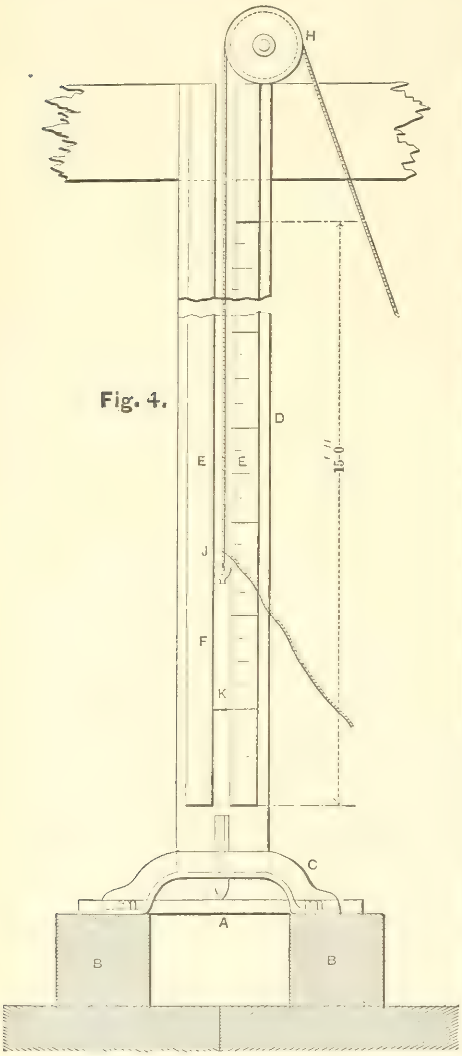


Fig. 4.

graduated quadrant G, which is set at zero at the commencement of each test.

In making the tests with transverse strains, the riding weight was used to ascertain the loads up to 1 ton, and, if the bar did not break, was brought to zero, and a weight representing 1 ton placed on the rod L, the riding weight being then used again up to the breaking point. The deflections were not self-registering, but were carefully noted as the loads were increased.

The apparatus used for determining the effects of temperature on bars, when subjected to impact, is shown in Figs. 4 and 5. The bar to be tested, A, was placed upon two heavy cast iron blocks B, kept in position by means of two angle-irons C, 4 inches apart, with distance blocks between. On the bottom edge of the back angle-iron rested a 2-inch plank D, 18 feet long, by 12 inches wide, bolted to the angle-iron at the bottom, and to a cross beam of the building at the top. To this plank were fixed guides E, for the falling weight F to run between. Between the angle-

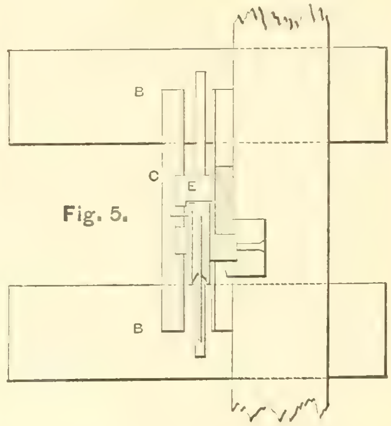


Fig. 5.

irons C were bolted the distance blocks G, shown to an enlarged scale in Fig. 6; between these again was placed a steel dolly 2 inches square, having an edge the width of the bar, and rounded to a radius of $\frac{1}{2}$ inch; the dolly rested on the top of the test bar, the force of the falling weight being transmitted through it. To the front of the dolly was screwed a piece of hard wood, a space being left in the distance-blocks for it to work freely without touching the blocks or the angle-iron, and to this wood was fixed a strip of paper, a fresh piece being used for each test bar, and on it was carefully marked the permanent set after each successive blow. The falling weight was a piece of 3-inch-square iron, weighing 40 lbs.; it was lifted by a rope passing over a pulley H, and released at any height, by pulling a light cord attached to a simple disengaging

hook J. The guides E were marked every 6 inches up to 15 feet, which was the limit of the fall, a small pointer K being fastened to the falling weight. A record of the height of each blow was kept, and the deflections read off the slip of paper were placed opposite to the corresponding fall, as shown in Tables V., VI., VII. and VIII.

When the bars were tested at low temperatures, they were taken from the freezing mixture, in which they had been lying for three hours, and placed in position in a wooden box fitted between the iron blocks, the box being filled with a freezing mixture of snow and salt. The bar was kept covered during the whole time the test was being made. At the back of this box a small recess was fitted, A in Fig. 7 and 8, and arranged so as to press against the test bar, being kept in position by a stop B, fixed on the other side; thus a portion of the bar was kept dry, and the recess free from the action of the mixture in the box. Into this recess was inserted the bulb of a thermometer touching the bar, and packed behind with cotton wool to exclude the external atmosphere. By these means a near approximation to the temperature of the bar was obtained.*

Fig. 6.

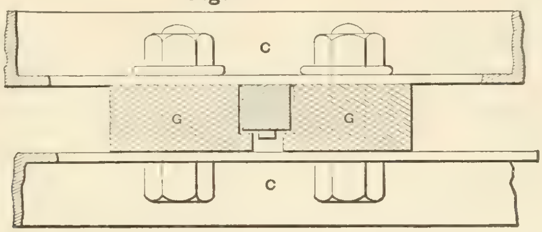
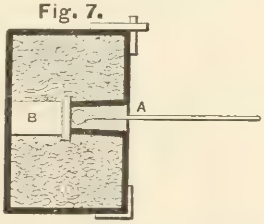


Fig. 7.

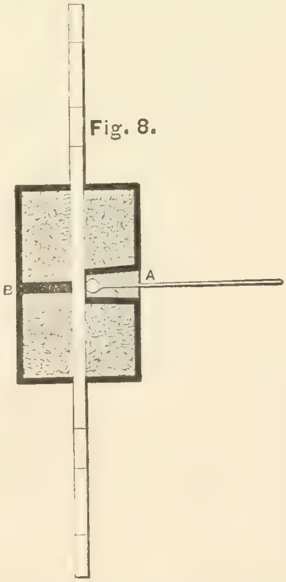


Although the freezing mixture was at zero, the temperature of the test bar was found in every case to be about 5° Fahrenheit, the difference of the two temperatures being due, no doubt, to conduction through the connections of the bar with the testing machine.

EXPERIMENTS ON WROUGHT IRON BARS SUBJECTED TO TENSILE STRAINS.

The first experiments were made with twelve flat bars, six of them being originally 6 inches broad by $\frac{1}{2}$ inch thick, and the others $3\frac{1}{2}$ inches by $\frac{1}{2}$ inch. They were rolled from the same pile, but to prevent any error arising from the difference of the two sections, three bars of

Fig. 8.



* The author originally intended to have observed the temperature of the test bars by a thermopile and galvanometer, one cone of the thermopile being placed in the recess next the exposed portion of the bar, and the other cone next a Leslie's cube; the difference of the temperatures being observed by the position of the reflected light of the galvanometer; but as he was disappointed in not having the apparatus completed in time for the experiments, he was compelled to use the thermometer. Although this apparatus would have been more sensitive to the variations in temperature, the recorded temperatures may be considered sufficiently accurate for the object of the present experiments. The thermometer was allowed to remain next the bar for about twenty minutes before the observations were taken, the bar being covered the whole of the time with the freezing mixture.—J. J. W.

each were tested at the low temperature, and three of each at the ordinary temperature. After the holes for the coupling pins had been bored, great care being taken that a line joining the two centers passed exactly through the center of each bar, they were placed upon a mandrel, and all shaped together to a width of $1\frac{1}{2}$ inch for a length of $6\frac{1}{2}$ inches in the center of the bar, a uniformity of the sections being thus ensured. Although pins were used for attaching the test bars to the machine, the plan of using serrated steel wedges or "dogs" is far preferable; for by that means a large amount of skilled labor is dispensed with in preparing the test bars, and there is not the same chance of errors arising from the direction of the tensile strain not passing through the center line of each bar. After leaving the shaping machine, each bar was carefully examined and numbered; and on the center line, which was marked with a fine scriber, two center punch dots were made at a distance of $6\frac{1}{4}$ inches apart, this length being the one taken to ascertain the ultimate extension. The distance adopted by various authorities is generally either 6, 8, or 10 inches, but the $6\frac{1}{4}$-inch gauge is a most convenient one, for by adopting it the percentage of elongation can be read off at once, every $\frac{1}{16}$ inch being equivalent to 1 per cent.*

As it was intended to observe, in addition to the ultimate extension, the amount which took place at different portions of the test bar, the distance of $6\frac{1}{4}$ inches was divided into six equal parts, accurately set out and marked with a center punch; and as there was a possibility of the bar breaking outside either of the two end marks, a length equal to one of the divisions was marked beyond them.

The wrought iron test bars were cut from flat bars made from faggoted scrap, and manufactured by the Hull Forge Company.

The malleable cast iron test bars were cast by Messrs. Andrew Handyside and Company, Derby, from a pattern made to the required shape, the width in the center being $\frac{1}{8}$ inch larger than the finished size, to enable them to be all shaped exactly to the section, after which they were set out and marked as before. The net sectional area of the bars was 0.75 inch.

The steel bars for the tensile tests were of Bessemer steel, manufactured by Messrs. Brown, Bailey and Dixon, the test strips being cut from a bar $4\frac{1}{2}$ inches wide by $\frac{5}{8}$ inch thick, shaped and set out as before, the net sectional area being 0.62 inch.

The results of the experiments with tensile strains are shown in Tables I., II. and III., in which are recorded the breaking strain per square inch of the original section, the percentage of extension, and the reduction of area at the fracture. The extension of the bars between the several points marked in their length is shown on Plates 8 and 9, where the thick horizontal lines, from the center of each of the six divisions, represent the percentage of extension of the bars at those points, and can be read off by the vertical lines, which are drawn to a scale of $\frac{1}{8}$ inch to 1 per cent. The total percentage of extension is given at the bottom of each diagram, underneath which is shown the original section of the bar, with the reduced section inside, shaded to show also the nature of the iron at the fracture. The malleable iron castings are not represented by similar diagrams, for the total extension of the bar is so very small that the amount between each of the six divisions would be hardly perceptible.

It is the general opinion that, when a bar is tested, the extension along its length is uniform, except at that portion where the fracture takes place; that is to say, all the horizontal lines, except the one at fracture, would be equal. The result of these experiments, however, shows that such is not the case, the irregularities, in some instances, especially those for wrought iron, being conspicuous. This is important, as it raises the question of the value of the reduction of area as a measure of the ductility of the material; for it is possible to have a reduction of area, with a large permanent extension, the latter condition being, in the author's opinion, the best

* It would be far better, and would simplify matters considerably, if engineers would adopt some standard length from which to measure the amount of extension. Comparisons of results of different experiments could then be correctly made, whereas, at present, the specified extension of any material is an ambiguous quantity, depending upon the length adopted, which, in many published tables of results, and in many specifications, is never mentioned.—J. J. W.

indication of the qualtity of ductility. The breaking strain is also occasionally expressed in terms of the reduced area of the fracture; but this can hardly be of much value, for the extension or reduction of area and the breaking strain represent two distinct qualities of the material, and one cannot be well expressed in terms of the other. Of two bars, one bar might possibly have a high breaking strain with a small reduction of area, and the other a low breaking strain with a proportionally large reduction of area; and if the above plan were adopted, the results obtained would have the same numerical value. Again, it is possible, and probable, in a bar of very ductile material, that before it actually breaks the strain is reduced; that is to say, the real strain required at last to part the bars is less than that applied before the ultimate extension takes place; and as this strain cannot be easily measured, owing to the suddenness of the change, it shows clearly that the breaking weight recorded is the amount required to fracture the bar of a certain original section; and should this amount be expressed in terms of the fractured area no real value can be attached to it.

EXPERIMENTS ON CAST IRON BARS SUBJECTED TO TRANSVERSE STRAINS.

Owing to almost the impossibility of breaking bars of wrought iron or steel with a transverse strain, on account of the great deflection which takes place before fracture, these experiments were limited to sample bars of cast iron. Twelve bars were experimented upon, six at 50°, and six at 5° Fahrenheit. Each bar was 3 feet 6 inches long, by 2 inches deep, 1 inch wide, and rested on its edge on supports 3 feet apart, in the crosshead shown in Figs. 2 and 3. When the bars were tested at the lower temperature they were covered with snow for three days, and for three hours previous to the test with the freezing mixture, with which they were also covered during the test, in a long trough fitting up to the crosshead, the front being hinged to enable the bar to be withdrawn, and another inserted. The results of these experiments are recorded in Table IV., where the breaking strain of each bar is given in cwts., and the deflection before fracture in inches.

EXPERIMENTS ON BARS SUBJECTED TO IMPACT.

The materials used in these experiments were wrought iron, best tool steel, cast iron, and malleable cast iron; twelve bars of each material being tested, six of each at 50°, and 6 of each at 5° Fahrenheit. Those tested at the lower temperature were under exactly similar conditions to those which were subjected to tensile and transverse strains, as already described.

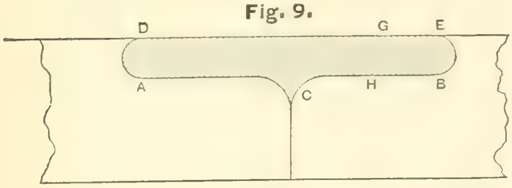
In testing the wrought iron bars, the same difficulty was experienced with the great deflection as occurred when transverse strains were applied. Bars $1\frac{1}{2}$ inch square, resting on supports 18 inches apart, could not be broken with a falling weight of 40 lbs., but were doubled up to an angle less than a right angle, and still showed no signs of fracture. Bars 1 inch square, resting on supports 9 inches apart, were then tried, with similar results; and it was not until iron was adopted of a smaller section, of a common quality, and with reduced bearings, that satisfactory results could be obtained. The twelve bars finally tested were of common iron, $\frac{3}{4}$ inch square, resting on supports 6 inches apart. The results of these experiments are recorded in Table VI., where the height of fall of a 40-lb. weight and the permanent deflection at each successive blow are given. The height from which the weight fell when the bar broke is not given, for in most cases, although this height was above the last recorded one, a fall of a few feet only would have sufficed to break the bar, and it may be fairly assumed that it was the previous blow which destroyed it.

The steel bars tested by impact were of best cast tool steel, 1 inch square, and were placed upon supports 18 inches apart. The samples were all cut from two bars rolled at the same time, and although it might be supposed that they were practically alike, the wide range of the results is very marked, the height of fall varying from 6 feet to 15 feet. The fracture of these bars was most curious, for in every instance, both at the ordinary temperature and at the lower temperature, it took the form shown in Fig. 9, the shaded portion coming away from the top side, and flying a considerable distance. These pieces were not always of the same size, and occasionally were

broken across the part shown by the dotted line at G H, but they were all of the same shape, and possessed the same peculiarities. The ends at D and E were rounded, both as shown in elevation in Fig. 9, and in plan in Fig. 10, the ends of the bar being concave to correspond, and the loose piece then finished off with a sharp knife edge at C.

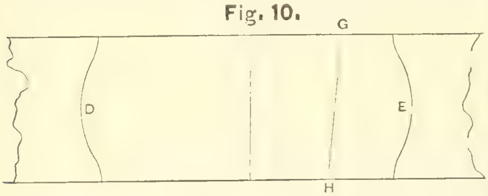
The under side of this piece, at the points A and B, was quite smooth, as if

Fig. 9.



there had been friction, and the probability is that, under the succession of blows delivered on the top of bar, it was drawn out, and as the portion of the bar above its neutral axis was in compression from the deflection, one portion was made to slide over the other, and thus the smooth surfaces at A and B were formed, the curves D A C, or E B C, evidently representing the neutral line of the two opposite forces. The bars at the lower temperature were prepared and tested under exactly the same conditions as those previously described. The results of these experiments are recorded in Table VII., where the height of fall and permanent deflection at each blow are given.

Fig. 10.



The malleable cast iron bars tested by impact were 3 feet 6 inches long, by $1\frac{1}{2}$ inch deep, by 1 inch wide, and were originally intended to have been broken with a transverse strain; but the deflection was again found to be so great that it was impossible to do so with the machine, the stroke of the piston not being long enough. The bars were placed upon supports 1 foot 6 inches apart, and were tested in the same manner, and under the same conditions as the other bars, six being at 50°, and six at 5° Fahrenheit. The falling weight was 40 lbs. The results of these experiments are recorded in Table VIII.

The ordinary cast iron bars tested by impact were 10 inches long, by 2 inches deep, by 1 inch wide, and rested on their edges upon supports 6 inches apart; the falling weight being 10 lbs. only, instead of 40 lbs., as in all the other experiments. The same number of bars was tested as before, and under similar conditions, the results being recorded in Table V.

SUMMARY OF RESULTS.

A summary is given in Table IX., where the average of each set of experiments is tabulated.

Upon examination, the results obtained by submitting the bars of wrought iron and Bessemer steel to a tensile strain will be found to a great extent to agree with those by M. Styffe. The figures show clearly that severe cold does not affect the tensile strengh of the materials, but that it increases the ductility of each of them.

When, however, cast iron bars are submitted to a transverse strain, the results show that both their strength and flexibility are considerably affected by the action of severe cold; and when all the four metals, wrought iron, cast iron, steel and malleable cast iron, are subjected to the force of impact, the same result is observed in each, viz., that at a low temperature it requires either a lower fall or a less weight to break them, and their flexibility is considerably diminished. This result is the one anticipated by Mr. Sandberg, and, although his opinion is to some extent confirmed by the present experiments, the differences observed in his experiments were far greater, perhaps, for the reasons already explained.

The results of the experiments may be summed up as follows, viz.:

1. When bars of wrought iron or of steel are submitted to a tensile strain and broken, their strength is not affected by severe cold (5° Fahrenheit), but their ductilty is increased about 1 per cent. in iron and 3 per cent. in steel.*

* As far as can be judged from the small number of malleable cast iron bars which fairly broke when at the low temperature, it would appear that tne tensile

2. When bars are submitted to a transverse strain at a low temperature, their strength is diminished about 3 per cent. and their flexibility about 16 per cent.

3. When bars of wrought iron, malleable cast iron, steel and ordinary cast iron, are subjected to a force of impact at a temperature of 5° Fahrenheit, the force required to break them, and the extent of their flexibility, are reduced as follows, viz.:

	Reduction of force of Impact. Per cent.	Reduction of Flexibility. Per cent.
Wrought iron........	about 3	about 18
Steel (finest cast tool).	" 1	" 17
Malleable cast iron...	" 4½	" 15
Cast iron............	" 21	not taken.

It will be noticed from the Tables that, when the malleable iron castings were tested with a tensile strain at the low temperature, four out of the six bars broke through the eye. This unfortunately interfered with a fair average being taken, but on the other hand, it strengthens the opinion that the material is influenced by the action of severe cold, for the sectional area of the bars through the eye was nearly twice that of the center, and as in most cases the metal was perfectly clean at the fracture, the bar was evidently not broken by a direct tensile strain, but by some indirect action.

It is difficult to reconcile the results of the experiments on impact with those with a tensile strain; one appears to contradict the other. It must, however, be remembered that the conditions under which the bars were broken at the low temperature were not identical in the two cases. When the bars were being broken by impact, it may be fairly assumed, that their temperature was constant; but when they were broken by a tensile strain, it certainly was not so, for on approaching the breaking point the temperature of the bars near the point of rupture increased considerably; instead of being at 5° Fahrenheit as at the commencement, it was much higher, notwithstanding the action of the freezing mixture. This rise of temperature is very sudden, and would probably only affect the ultimate breaking strain, and not the extension, which most likely would have taken place before the rise commenced; yet it is hard to conceive why the material should extend more in the cold, unless it be that the evident contraction or altered position of the particles tends in some way to increase its facility for being drawn.

The question now arises, which of the results is to be taken as indicating the real condition of iron and steel at the low temperature, those obtained from the experiments with tensile strains, or those obtained from the experiments by impact? As both materials, when manufactured into rails, tires, axles, chains, &c., are, when in use, continually subjected to sudden shocks or blows, and as there appears to be a doubt about the correctness of the results obtained by tensile strains on account of the great heat evolved before fracture raising the temperature of the bars above freezing point, the author is of opinion that the conditions under which the tests with the falling weight were made approached nearest to those of the material when in use; and the results so obtained, should fairly represent the structural condition of the material when tested.

Although these results show that both wrought iron and steel are influenced by severe frosts, the reduction of their strength and ductility is so small, that in designing any new structures or machines it may be safely neglected. Great care should, however, be taken to prevent them from being subjected to more shocks and blows than necessary, and the examination of rolling stock and permanent way should be made frequently during frosty weather.

The results obtained with cast iron bars show the state of affairs to be much more serious, and consequently every precaution should be taken to protect all cast iron work subjected to transverse strains, as in girders, long columns, gearing, &c., from the action of frost; and should this be not practicable, the working loads ought to be reduced at least 25 per cent., notwithstanding the large factor of safety generally adopted in the original design.

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strength of the material is not influenced by the action of severe frost, but that its ductility is decreased.—J. J. W.

APPENDIX.

Table I.—Effects of Temperature on the Tensile Strength of Wrought Iron.

Number of Test.	Description of Material.	Makers' Name.	Original Sectional Area of Test Strip.	Temperature. Fahrenheit.	Breaking Weight per sq in. of original Section.	Area of Strip at Fracture.	Reduction of Area.	Permanent Extension in a Length of 6¼ ins.	Remarks.
	Ins. In.		Sq. in.	°	Tons.	Sq. In.	Per cent.	Per cent.	
1	Flat bar iron, 4½ × ½	Hull Forge Co.	0.75	5	24.80	0.60	20.0	22.8	
2	" "	"	0.75	5	24.57	0.61	18.8	22.0	
3	" "	"	0.75	5	24.29	0.59	21.7	14.7	
4	" 6 × ½	"	0 75	5	23.38	0.56	25.6	20.8	
5	" "	"	0.75	5	25.37	0.60	20.0	21.0	
6	" "	"	0.75	5	22.18	0.60	20.0	12.6	
	Average..........................		0.75	5	24.09	0.59	21.7	19.8	
7	Flat bar iron, 4½ × ½	Hull Forge Co.	0.75	50	25.00	0.56	25.6	20.2	
8	" "	"	0.75	5	22.76	0.66	12 0	11.8	Broke through neck—not included in average.
9	" "	"	0.75	5	23.68	0.65	13.3	16.1	
10	" 6 × ½	"	0.75	5	24.73	0.63	16.1	19.1	
11	" "	"	0.75	5	25.00	0.63	16.1	18.6	
12	" "	"	0.75	5	24.38	0.62	17.5	19.8	
	Average..............................		0.75	50	24.26	0.62	17.5	18.7	

TABLE II.—EFFECTS OF TEMPERATURE ON THE TENSILE STRENGTH OF STEEL.

Number of Test.	Description of Material.	Makers' Name.	Original Sectional Area of Test Strip.	Temperature. Fahrenheit.	Breaking Weight per sq. in. of original Section.	Area of Strip at Fracture.	Reduction of Area.	Total Permanent Extension.	Remarks.
	Ins. In.		Sq. In.	°	Tons.	Sq. In.	Per cent.	Per cent.	
1	Bessemer steel flat bar, $4\frac{1}{2} \times \frac{3}{8}$	Messrs. Brown, Bailey & Dixon	0.62	5	45.12	0.40	36.0	19.2	The bars contracted more in center than at the edges.
2	" "	"	0.62	5	45.84	0.38	38.5	20.3	
3	" "	"	0.62	5	47.61	0.42	32.2	20.1	
4	" "	"	0.62	5	45.80	0.46	25.6	20.0	
5	" "	"	0.62	5	47.60	0.46	25 6	16.5	
6	" "	"	0.62	5	45.74	0.42	32.2	17.0	
	Average..............................		0.62	5	46.29	0.42	32.2	18.8	
7	Bessemer steel flat bar, Ins. In. $4\frac{1}{2} \times \frac{3}{8}$	Messrs. Brown, Bailey & Dixon	0.62	50	46.75	Not measured	...	....	Broke at neck thus—
8	" "	"	0.62	50	46.64	0.43	31.2	15.6	
9	" "	"	0.62	50	45.48	0.43	31.2	15.9	
10	"	"	0.62	50	....	....	....	....	Broke through neck—no measurements recorded.
11	" "	"	0.62	50	....	....	....	....	Broke through neck—results not included in average.
12	" "	"	0.62	50	45.66	0.40	36.0	14.9	
	Average..................	....	0.62	50	46.13	0.42	32.2	15.4	

TABLE III.—EFFECTS OF TEMPERATURE ON THE TENSILE STRENGTH OF MALLEABLE CAST IRON.

Number of Test.	Description of Material.	Makers' Name.	Original Sectional Area of Test Strip.	Temperature. Fahrenheit.	Breaking Weight per sq. in. of original Section.	Total Permanent Extension.	Reduction of Area.	Remarks.
			Sq. in.	°	Tons.	Per cent.	The reduction was so small that it was not recorded, but in no case did it exceed 2 per cent.	
1	Test bar cast to shape	Messrs. Andrew Handyside & Co., Derby	0 75	50	24.6	2.0		
2	" "	"	0.75	50	24.0	1.0		Broke through eye—no flaw.
3	" "	"	0.75	50	24.2	2.5		
4	" "	"	0.75	50	17.6	2.1		
5	" "	"	0.75	50	23.5	1.7		
6	" "	"	0.75	50	25.2	1.5		Broke through eye—flaw in casting.
	Average of bars 1, 3, 4 and 5..........		....	50	22.4	2.1		
7	Test bar cast to shape	Messrs. Andrew Handyside & Co., Derby	0.75	5	23.0	2.0		
8	" "	"	0.75	5	....	...		Broke through eye—flaw in casting.
9	" "	"	0.75	5	....	...		Broke through eye—no flaw.
10	" "	"	0.75	5	21.5	1.0		
11	" "	"	0.75	5	....	...		" " "
12	" "	"	0.75	5	....	...		" " "
	Average of bars 7 and 10.............		....	5	22.2	1.5		

TABLE IV.—EFFECTS OF TEMPERATURE ON THE TRANSVERSE STRENGTH OF CAST IRON.

Number of Test.	Section of Test Bar.	Distance between Points of Support.	Breaking Weight.	Deflection before Fracture.	Temperature. Fahrenheit.
	Ins. In.	Feet.	Cwt.	Inch.	°
1	2 × 1	3	27.8	0.29	50
2	"	"	29.0	0.30	"
3	"	"	29.4	0.31	"
4	"	"	30.4	0.35	"
5	"	"	27.4	0.29	"
6	"	"	27.8	0.34	"
	Average		28.6	0.31	
7	2 × 1	3	26.4	0.23	5
8	"	"	23.4	0.24	"
9	"	"	Not broken.	..	"
10	"	"	29.4	0.27	"
11	"	"	31.8	0.31	"
12	"	"	28.4	0.29	"
	Average		27.8	0.26	

NOTE.—Owing to an irregularity in the casting, bar No. 9 would not enter the testing machine and was not broken.

TABLE V.—EFFECTS OF TEMPERATURE ON CAST-IRON BARS WHEN SUBJECTED TO IMPACT.

Weight of monkey, 10 lbs.

Number of Test.	Length of Bar.	Section of Bar.	Distance between Points of Support.	Height of Fall required to Break the Bar.	Temperature. Fahrenheit.
	Inches.	Ins. In.	Inches.	Ft. Ins.	°
1	10	2 × 1	6	3 9	5
2	"	"	"	3 7	"
3	"	"	"	3 5	"
4	"	"	"	3 10	"
5	"	"	"	4 4	"
6	"	"	"	3 8	"
	Average			3 9	
7	10	2 × 1	6	5 0	50
8	"	"	"	4 8	"
9	"	"	"	4 9	"
10	"	"	"	4 11	"
11	"	"	"	4 9	"
12	"	"	"	4 7	"
	Average			4 9⅓	

TABLE VI.—EFFECTS OF TEMPERATURE ON WROUGHT-IRON BARS WHEN SUBJECTED TO IMPACT.

Length of test bars ....18 inches.
Section of " .... ⅞ inch square.

Distance between points of support........ 6 inches.
Weight of monkey................ ....40 lbs.

	Temperature 50° Fahrenheit.												Temperature 5° Fahrenheit.											
No. of Test	1		2		3		4		5		6		7		8		9		10		11		12	
No. of Blow.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.
	ft. ins.	in.	ft ins.	in.	ft. ins.	in.	ft ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.
1	4 0	0.20	3 0	0.08	3 0	0.12	4 0	0.14	4 0	0.16	4 0	0.22	6 0	0.28	5 0	0.52	4 0	0.10	3 0	0.08	3 0	0.24	3 0	0.06
2	4 6	0.28	3 6	0.20	3 6	0.24	4 6	0.32	4 6	0.36	4 6	0.34	7 0	0.52	+	b'ke	4 6	0.38	3 6	0.18	3 6	0.28	3 6	0.18
3	+	b'ke	4 0	0.32	4 0	0.34	5 0	0.52	5 0	0.50	5 0	0.44	+	b'ke	..	..	+	b'ke	4 0	0.34	4 0	0.48	4 0	0.32
4	..	..	4 6	0.42	4 6	0.50	+	br'ke	5 6	0.64	5 6	0.64	..	..	..	..	..	..	4 6	0.44	4 6	0.54	4 6	0.48
5	..	..	5 0	0.56	5 0	0.60	..	..	6 0	0.84	+	br'ke	..	..	..	..	..	..	+	br'ke	5 0	0 70	5 0	0.64
6	..	..	5 6	0.76	5 6	0.84	..	..	6 6	1.10	..	..	..	..	..	..	..	..	..	..	+	br'ke	5 6	0.80
7	..	..	+	b'ke	6 0	0.98	..	..	+	br'ke	..	..	..	..	..	..	..	..	..	..	..	..	6 0	0 92
8	..	..	..	..	+	b'ke	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+	br'ke

Average ultimate fall.................5 feet 6 inches.
" " deflection ....0.71 inch.

Average ultimate fall...........5 feet 4 inches.
" " deflection......0.58 inch.

TABLE VII.—EFFECTS OF TEMPERATURE ON STEEL BARS WHEN SUBJECTED TO IMPACT.

Length of test bars................18 inches.
Section of " .... 1 inch square.

Distance between points of support........6 inches.
Weight of monkey...........................40 lbs.

No. of Test	Temperature 50° Fahrenheit.												Temperature 5° Fahrenheit.											
	1		2		3		4		5		6		7		8		9		10		11		12	
No. of Blow.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.
	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.
1	1 0	0.04	1 0	0.02	2 0	0.00	4 0	0.02	4 0	0.18	2 0	0.00	1 0	0.00	3 0	0.01	2 0	0.00	4 0	0.02	3 0	0.01	3 0	0.01
2	1 6	0.05	1 6	0.06	3 0	0.01	4 6	0.04	5 0	0.22	3 0	0.08	2 0	0.01	3 6	0 02	2 6	0.01	5 0	0.10	4 0	0.02	4 0	0.08
3	2 0	0.06	2 0	0.08	4 0	0.08	5 0	0.05	6 6	0.42	4 0	0.14	3 0	0.02	4 0	0.08	3 0	0.04	6 0	0.28	4 6	0.06	5 0	0 16
4	2 6	0.08	2 6	0.12	5 0	0.22	5 6	0.10	7 6	0.62	5 0	0.16	3 6	0.04	4 6	0.12	3 6	0.06	7 0	0.38	5 0	0.10	5 6	0.26
5	3 0	0.14	3 0	0.18	+	b'ke	6 0	0.22	8 0	0.68	6 0	0.18	4 0	0.06	+	b'ke	4 0	0.10	8 0	0.52	5 6	0.14	6 0	0.30
6	3 6	0.16	3 6	0.20	..	..	6 6	0.24	9 0	0.84	+	br'ke	4 6	0.10	..	..	4 6	0.12	9 0	0.62	6 0	0.16	6 6	0 42
7	4 0	0.18	4 0	0.22	..	..	7 0	0.34	10 0	0.98	..	..	5 0	0.14	..	..	5 0	0.20	10 0	0.78	6 6	0 20	7 0	0.46
8	4 6	0.20	4 6	0.26	..	..	7 6	0.36	11 0	1.20	..	..	5 6	0 20	..	..	5 6	0.24	11 0	0.88	+	br'ke	7 6	0.50
9	5 0	0.25	5 0	0.30	..	..	8 0	0.48	12 0	1.34	..	..	6 0	0.28	..	..	6 0	0.30	12 0	1.02	..	..	8 0	0.64
10	+	b'ke	5 6	0.34	..	..	8 6	0.62	13 0	1.56	..	..	6 6	0.34	..	..	6 6	0.40	12 6	1.04	..	..	8 6	0.72
11	..	..	6 0	0.40	..	..	9 0	0.72	14 0	1 60	..	..	+	b'ke	..	..	+	b'ke	13 0	1.10	..	..	+	br'ke
12	..	..	6 6	0.46	..	..	9 6	0.80	+	br'ke	..	..	..	..	..	..	..	..	13 6	1.18				
13	..	..	7 0	b'ke	..	..	+	br'ke	..	..	..	..	..	..	..	..	..	..	+	br'ke				

Average ultimate fall...... ....7 feet 9 inches.
" " deflection...... .....0.59 inch.

Average ultimate fall................7 feet 8 inches.
" " deflection..........0.49 inch.

TABLE VIII.—EFFECTS OF TEMPERATURE ON MALLEABLE CAST IRON BARS WHEN SUBJECTED TO IMPACT

Length of test bars.................. ...3 feet 6 inches.
Section of " ....$1\frac{1}{2}$ inch × $\frac{3}{4}$ inch.

Distance between points of support..............18 inches.
Weight of monkey. ....40 lbs.

Temperature 50° Fahrenheit.

No. of Test	1		2		3		4		5		6	
No. of Blow.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.
	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.
1	1 0	0.08	3 0	0.12	4 0	0.26	4 0	0.22	4 0	0.16	4 0	0.14
2	2 0	0.12	4 0	0.24	5 0	0.32	5 0	0.30	5 0	0.30	5 0	0.42
3	3 0	0.26	5 0	0.42	6 0	0 48	6 0	0.44	6 0	0.44	+	br'ke
4	4 0	0.38	6 0	0.60	7 0	0.64	7 0	0.62	7 0	0.56	..	..
5	5 0	0.50	7 0	0.76	8 0	0.82	7 6	0.70	8 0	0.72	..	..
6	6 0	0.82	8 0	0.90	+	b'ke	8 0	0.84	8 6	0.86	..	..
7	7 0	0 96	+	b'ke	..	..	8 6	0.98	9 0	0.96	..	..
8	8 0	1.04	..	..	..	..	+	br'ke	+	br'ke	..	..
9	9 0	1.18	..	..	..	..	..	..	..	..	..	..
10	+	b'ke										

Average ultimate fall..........7 feet 11 inches.
" deflection.............0.88 inch.

Temperature 5° Fahrenheit.

No. of Test	7		8		9		10		11		12	
No. of Blow.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.	Height of Fall.	Permanent Deflection.
	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins.	in.	ft. ins	in.
1	4 0	0.14	4 0	0.20	4 0	0.20	4 0	0.14	4 0	0.12	4 0	0.18
2	5 0	0.24	5 0	0.30	5 0	0.40	5 0	0.16	5 0	0.32	5 0	0.38
3	6 0	0.50	6 0	0.50	6 0	0.54	6 0	0.36	6 0	0.54	+	br'ke
4	7 0	0.64	7 0	0.62	7 0	0.68	7 0	0.40	7 0	0.64	..	..
5	7 6	0.78	7 6	0.81	7 6	0.82	7 6	0.50	8 0	0 68	..	..
6	8 0	0.82	+	b'ke	+	b'ke	8 0	0.60	8 6	0.92	..	..
7	+	b'ke	..	..	..	..	8 6	0.66	+	br'ke	..	..
8	..	..	..	..	..	..	9 0	0 76				
9	..	..	..	..	..	..	+	br'ke				
10												

Average ultimate fall..........7 feet 7 inc es.
" deflection.............0.75 inch.

TABLE IX.—SUMMARY OF RESULTS.

TENSILE STRAINS. (For details see Tables I., II., and III.)

Description of Material.	Sectional Area of Test Bar.	Average Breaking Weight per Square Inch.	Average Permanent Extension in Length of $6\frac{1}{4}$ inches.	Average Reduction of Area.	Temperature. Fahrenheit.
inches. inch.	sq. inch.	Tons.	per cwt.	per cent.	°
Wrought-iron flat bars $\left\{\begin{matrix} 6 \times \frac{1}{2} \\ 4\frac{1}{2} \times \frac{1}{2} \end{matrix}\right\}$	0.75	24.09	19.8	21.7	5
" " "	0.75	24.26	18.7	17.5	50
Bessemer steel " $4\frac{1}{2} \times \frac{5}{8}$.	0.62	46.29	18.8	32.2	5
" " "	0.62	46.13	15.4	32.2	50
Malleable cast iron	0.75	22.20	1.5	..	5
" "	0.75	22.40	2.1	..	50

TRANSVERSE STRAINS. (For details see Table IV.)

Description of Material.	Sectional Area of Test Bar.	Distance between Points of Support.	Average Breaking Weight per Square Inch.	Average Deflection before Fracture.	Temperature. Fahrenheit.
Ft. Ins. Ft. In.	sq. inches.	feet.	cwt.	inch.	°
Cast-iron bars, 3 6 × 2 × 1.	2	3	27.8	0.26	5
" " " "	2	3	28.6	0.31	50

IMPACT. (For details see Tables V., VI., VII., and VIII.)

Description of Material.	Section of Test Bar.	Distance between Points of Support.	Average Height of Fall.	Average Permanent Deflection.	Temperature. Fahrenheit.
	sq. inches.	inches.	feet ins.	inch.	°
Wrought-iron bars	$\frac{7}{8}$	6	5 4	0.58	5
" "	$\frac{7}{8}$	6	5 6	0.71	50
Best cast tool steel bars.........	1	18	7 8	0.49	5
" "	1	18	7 9	0.59	50
Malleable cast-iron bars.........	$1\frac{1}{2} \times \frac{3}{4}$	18	7 7	0.75	5
" "	$1\frac{1}{2} \times \frac{3}{4}$	18	7 11	0.88	50
Cast-iron bars..................	2×1	6	3 9	Not perceptible.	5
"	2×1	6	4 $9\frac{1}{3}$		50

TABLE X.—CHEMICAL ANALYSES OF THE MATERIALS USED IN THE EXPERIMENTS.*

Materials.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Graphite	Iron (by Difference).	Total.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Bessemer steel........	0.400	0.079	0.107	0.044	1.001	....	98.369	100.000
Cast tool steel........	1.145	0.121	0.042	0.013	0.197	....	98.482	100.000
Best bar iron.........	0.060	0.158	0.073	0 256	trace.	....	99.453	100.000
Malleable cast iron.. .	2.085	0 499	0.446	0 021	0.183	....	96.766	100.000
Ordinary cast iron....	0.300	1.618	0.119	1.107	0.563	2.643	93.650	100.000
Common bar iron	0.067	0.136	0.036	0.347	0.016	....	99 398	100.000

* These analyses were made by Mr. Edward Richards, F. I. C., Chemist to the Barrow Hæmatite Steel Company, Limited.

THE ARCHÆOLOGY OF THE CUMBERLAND IRON TRADE.

From "The Architect."

A paper on "The History of Iron Manufacture in West Cumberland" was read by Mr. H. A. Fletcher, at the meeting of the Cumberland and Westmoreland Archæological Society.

Mr. Fletcher said, that, although the different modes of iron-making known to successive ages from the Roman bloomery, from which a small portion of malleable iron was extracted from the richer ores in a tiny furnace urged by the natural force of the wind, followed afterward by a slightly improved furnace, worked by hand bellows, and a little later by the force of bloomsmithy, with bellows or other blowing machinery driven by water-power, as well as the smelting of pig iron in blast furnaces, first with charcoal as fuel and then with pit coal, or rather coke, together with the making of wrought iron from the pig in the open hearth, until superseded by the invention of the art of puddling by Henry Cort, have all been practiced in West Cumberland, it had only been after long intervals and on small scales, and it was only within our own time that this division of the county had become a great iron producing center. The rich red hematite iron ore of Cumberland could not escape the watchful eyes of its Roman occupiers; but it is a little remarkable that, so far as the writer is aware, no vestiges of the scoriæ of Roman iron bloomeries have been found in the parts where the ore is most abundant, such as Egremont, Cleator, and Frizington; but possibly cultivation of the soil may have obliterated all traces, and it is not improbable that such stray pieces of kidney ore as may have been found in other parts on the surface of the ground or in the beds of streams, and the vein-like deposits in the crevices of some of the mountain rocks, may have been sufficient for their limited make. At the foot of Wastwater Lake there was every indication of there having been a veritable bloomery. That iron making was practiced in this part in the twelfth century they had proof from the Chartulary of the Abbey of Holme Cultram. Traces of charcoal furnaces had been found in various places on excavations being made. Coming to the period when the smelting of iron in blast furnaces with coke as fuel became an established commercial success, which was not until after 1735, we find that about the middle of the eighteenth century such furnaces were built within the Cumberland coalfield, most or all of them with furnaces attached for making iron castings, at four different places—viz., Little Clifton, Maryport, Seaton, and Frizington; but little success seems to have attended them, for these works all seem to have been abandoned after but short careers, except those at Seaton. About 1750, or possibly

a little earlier, Messrs. Cookson & Co., who worked coal mines at Clifton and Greysouthen, erected a blast furnace near Little Clifton, on the banks of the river Marron, which supplied the needful water power for blowing. The site is still distinguishable, and a few cottages at a little distance for the use of the workmen retain the name of Furnace Houses. There was a foundry in connection with the works, where light castings, for the use of mill-wrights and farmers, were made, as well as those required at the proprietors' own colliery. On the neighboring roads may be found pieces of the furnace slag with which they have been repaired, and many of these are of a character which indicate a not very satisfactory result in smelting. The old furnace at Maryport was built in 1752. It was square in cross section, and appeared to have been about 36 feet high and 11 or 12 feet diameter at the "boshes," or widest part. The Seaton Ironworks, near Workington, were established in 1762. The blast furnace had been in use here, and cast and wrought iron manufactured. But little information had been gathered respecting the furnace at Howth Gill, Frizington, for, unfortunately, who could have best given it had passed away, but an inspection of the ground showed two circular excavations about 12 yards in diameter, 6 or 8 feet deep, and about 24 yards apart, which are clearly the sites of two blast furnaces of considerable size. An attempt had been made at Frizington to manufacture wrought iron direct from the ore with pit coal from 1728 to 1730. In 1799, Adam Heslop, along with his brothers Crosby and Thomas, and several other partners, under the style of Heslops, Millward, Johnson & Company, founded the Lowca Ironworks, with a view of smelting, in addition to the iron foundries which they then erected, along with appliances for making the Heslop Patent steam engines; but after laying the foundations of two blast furnaces, abandoned them. Their lease of the site from Mr. J. C. Curwen included the right of working the thin bands of clay ironstone, of the coal measures which crop out on the beach in Harrington parish, as well as some other mineral rights. This was the last attempt to establish blast furnaces in the West Cumberland coalfield, until the Whitehaven Hematite Iron Company built their works at Cleator Moor in 1841. At the Flosh, Cleator, where Mr. Ainsworth's Flax Mills now stand, there were some works for making bar iron and steel, which were abandoned and dismantled in 1799. The earliest record which has been found of iron ore mining in Cumberland seems to be the grant of the forge at Winefel to the monks of Holm Cultram Abbey in the twelfth century, which also included a mine at Egremont (by inference of iron, being in connection with a forge); and Thomas de Multon confirms a gift to the same Abbey, "de quaruor duodenis minæ ferri in Coupland." In the latter half of the seventeenth century ore was worked to a considerable extent at Langhorn, near Egremont, where there was a deposit close to the surface, excavated in the open like a stone quarry. Much of the ore raised in 1749 was shipped at Parton in small craft, carrying from 10 to 61 tons, to Chester, to be smelted in a furnace belonging to Mr. Gee, and situated either near Wrexham or in Shropshire, it is not quite clear which. The ore stored at Parton under a shed for the purpose, ready for rapid shipment, was most likely carried there on the backs of horses, for it does not seem at that time there was any direct road from Frizington passable by wheeled vehicles, Ore seems to have been worked freely at Cleator a century ago, and at Crossfield some fifty years earlier. In the Millom district, Mr. Massicks is of opinion that no part of the vast deposits at Hodbarrow were touched till about fifty years ago, when a small quantity was worked near the shore, and that the Huddlestone furnaces were partly supplied from a small vein in the limestone close by, the remainder being brought from Furness.

A VIKING'S SHIP.

From "The Architect."

The correspondent of *The Times* in Copenhagen gives the following account of a remarkable discovery:

A recent antiquarian discovery of a most remarkable nature has put the scientific world of Scandinavia in commotion, and is attracting the general attention of the Scandinavian nations, fondly attached to their venerable history and ancient folk-lore, and full of devotion for the relics of the great past. In age this discovery cannot cope with the treasure-trove brought forth by Schliemann from Ilian or Grecian soil, nor even with the excavations conducted by German *savans* at Olympia. It only carries us back to a period distant a thousand years from our time, but still it initiates the modern time in the life and customs of bygone ages, and vivifies the cycle of old northern poems and sagas as fully as the "Iliad" is illustrated by the excavations at Hissarlik or at Mycenæ, or the Pindaric odes by those at Olympia.

In the southwestern part of Christiania Fjord, in Norway, is situate the bathing establishment of Sandefjord, renowned as a resort for rheumatic and nervous patients. The way from this place to the old town of Tönsberg conducts to a small village called Gogstad, near which is a tumulus or funereal hill, long known in the local traditions under the name of King's Hill (*Kongshaugs*). In the flat fields and meadows, stretching from the fjord to the foot of the mountains, this mole, nearly 150 feet in diameter, rises slowly from the ground, covered with green turf. A mighty king, it was told, had here found his last resting place, surrounded by his horses and hounds, and with costly treasures near his body, but for centuries superstition and the fear of avenging ghosts had prevented any examination of the supposed grave, until now the spirit of investigation has dared to penetrate into its secrets. The result has been the discovery of a complete vessel of war, a perfect Viking craft, in which the unknown chieftain had been entombed.

The sons of the peasant, on whose ground the tumulus is situate, began in January and February this year an excavation. They dug down a well from the top, and soon met with some timber. Happily they suspended their work at this point, and reported the matter to Christiania, where the "Society for the Preservation of Ancient Monuments" took up the task, and sent down Mr. Nicolaysen, an expert and learned antiquary, to conduct the further investigation. Under his able guidance the excavation was carried on in the months of April and May, and brought to a happy conclusion, revealing the whole body of an old Viking vessel, 74 feet long between stem and stern, 16 feet broad amidships, drawing 5 feet, and with twenty ribs. This is by far the largest craft found from the olden times. In 1863 the Danish Professor Engelhardt dug out from the turf-moor at Nydam, in Schlesvig, a vessel 45 feet in length, and in 1867 another was found at Tune, in Norway, 43 feet long; but neither of these can, in completeness or appointment, be compared with the craft now excavated at Gogstad. The tumulus is now nearly a mile distant from the sea, but it is evident from the nature of the alluvial soil that in olden times the waves washed its base. The vessel had consequently been drawn up immediately from the fjord, and placed upon a layer of fascines or hurdles of hazel branches and moss; the sides had then been covered with stiff clay, and the whole been filled up with earth and sand to form the funereal hill. But the craft is placed with the stem towards the sea. It was the grand imagination of the period that when the great Father of the Universe should call him, the mighty chieftain might start from the funereal hill with his fully-appointed vessel out upon the blue ocean.

In the stem of the ship, first disclosed to the eye, several interesting objects were found. A piece of timber proved to be the stock of the anchor; it was perforated to hold the iron, but of this

no more was found than a few remnants. In the bottom the remains of two or three small oaken boats of a very elegant shape were placed over a multitude of oars, some of them for the boats, others, 20 feet long, for the large craft itself. The form of these oars is highly interesting, and very nearly like those still in use in English rowing matches, ending in a small, finely-cut blade, some of them with ornamental carvings. The bottom-deals, as well preserved as if they were of yesterday, are ornamented with circular lines. Several pieces of wood had the appearance of having belonged to sledges, and some beams and deals are supposed to have formed compartments dividing the banks of the rowers on each side from a passage or corridor in the middle. In a heap of oaken chips and splinters was found an elegantly shaped hatchet, a couple of inches long, of the shape peculiar to the younger Iron Age. Some loose beams ended in roughly carved dragons' heads, painted in the same colors as the bows and sides of the vessel—to wit, yellow and black. The colors had evidently not been dissolved in water, as they still exist; but, as olive oil or other kinds of vegetable oil were unknown at the time, it is supposed that the colors have been prepared with some sort of fat, perhaps with blubber.

As the excavation proceeded, the whole length of the vessel was laid bare. All along the sides, nearly from stem to stern, and on the outside, extended a row of circular shields, placed like the scales of a fish. Nearly 100 of these are remaining, partly painted in yellow and black, but in many of them the wood had been consumed and only the central iron plate is preserved. From the famous tapestry of Bayeux it is well known that the ancient viking vessels had these rows of shields along the freeboard, but it was supposed that they were those used by the warriors in the strife, and only placed there for convenience. It is now clear that they had only an ornamental purpose, being of very thin wood, not thicker than stiff pasteboard, unable to ward off any serious hit from a sword. In the middle of the vessel a large oaken block, solidly fastened to the bottom, has a sqare hole for the mast, and several contrivances show that the mast was constructed for being laid down aft. Some pieces of tow and a few shreds of woollen stuff, probably the mainsail, were found here. In this part of the vessel was built the funereal chamber, formed by strong planks and beams placed obliquely against each other, and covering a room of nearly 15 feet square. Here, just as expectations were raised to the highest pitch, a bitter disappointment awaited the explorers. Somebody had been there before them. Either in olden times, when the costly weapons of an entombed hero tempted the surviving warriors, or in some more modern period when the greediness for treasure was supreme in men's minds, the funereal hill has been desecrated, its contents pilfered and dispersed, and what has been left is only due to the haste and fear under which the grave robbers have worked. A few human bones, some shreds of a sort of brocade, several fragments of bridles, saddles, and the like in bronze, silver, and lead, and a couple of metal buttons, one of them with a remarkable representation of a cavalier with lowered lance, are all that has been got together from the heap of earth and peat filling the funereal chamber. On each side of it, however, were discovered the bones of a horse and of two or three hounds. In the forepart of the ship was found a large copper vessel, supposed to be the kitchen caldron of the equipage, hammered out of a sole piece of copper, and giving a most favorable proof of that remote period's handicraft. Another iron vessel with handles, and with the chain for hanging it over the fire, lay close to a number of small wooden drinking cups. The detailed account of all these objects would claim too much space.

It was originally the intention to dig out the whole craft from the hill, and transport it to the Museum at Christiania. A large proprietor of the neighborhood, Mr. Treschow, offered to pay the expense. But on closer examination, and after consultation with one of the constructors of the navy, it was considered unsafe to attempt such a dislocation. It is now the intention to leave the craft where it was found, and to protect it against the influence of the weather by building a roof over the hill, only carrying to the Museum at Chris-

tiania the smaller objects. The Government has at once consented to defray the expenses necessary for the purpose.

As to the time when the tumulus was thrown up, there is no doubt among the antiquarians that it dates from the period termed the "younger Iron Age," distant from our day nearly a thousand years or a little more. We shall have to carry our thoughts back to about the year 800, when Charlemagne was crowned Emporer at Rome, but when Norway was still divided between the wild chieftains and sea-kings, vanquished towards the close of the ninth century by the great Harold, the Fair-haired, founder of the Norwegian state and nation.

THE STRENGTH OF RAILWAY BRIDGES.

From "The Engineer."

On the night of Thursday, the 17th inst., a very alarming accident occurred on the Hereford, Hay and Brecon Railway, a branch line worked by the Midland Company. A bridge of three arches, which carries the line across the river Wye at a point between Hay and Brecon, gave way, and a goods train fell into the river. The unfortunate engine-driver was killed on the spot, and the stoker was terribly injured. It is not yet quite certain either why or when the bridge fell. A very heavy train of twenty-four carriages filled with passengers had passed over it a few hours before. The river was in flood, and it is supposed that the foundations of the bridge were undermined and carried away; and that the bridge, possibly, had fallen before the goods train reached it. On these points, information, now lacking, will, of course, be forthcoming in due time. Meanwhile, we have presented for our consideration the broad fact that a railway bridge has fallen; that a goods train has gone into a river with a great destruction of property and the loss of life, and that a passenger train might just as well have gone in as a goods train, in which case, probably, two or three hundred lives would have been lost instead of one. The circumstances of the accident are in no wise unique. A trumpery little bridge near Beckenham broke down because of a flood some years ago, and many lives were lost. The Ashtubula accident in America is no doubt fresh in the minds of many of our readers. The Tay Bridge we need hardly name. Last year two bridges, one at Llandulas and the other at Aber in North Wales, were washed away, so to speak, and nothing but apparently excessive vigilance avoided one frightful calamity or two; and we think we are justified now in asking whether railway companies and their engineers attach sufficient importance to some points connected with bridges, and whether a great many bridges might not be found all over the country which are really unsafe.

There are in Great Britain thousands of little railway bridges, varying in span between 20 feet and 80 feet, which were put up many years ago, and which have received scant attention since; not a few of these bridges must now be in a more or less dangerous condition. It is not difficult to prove this statement. By the Board of Trade rules, wrought iron must not be strained to more than five tons per square inch in a girder, and cast iron should not have much over 1 ton per inch put on it. Now there are railway bridges in this country which have been standing for over thirty years; some of these are nearly half a century old. Let us confine our attention to the more recent bridges. These were put up at a time when the greatest weight of an engine and tender together did not much, if at all, exceed 40 tons. Twenty-five tons for an engine and 15 tons for a tender were abnormal weights rather than the reverse. Bridges of less than 60 feet span would take such an engine and tender upon them, and this weight of 40 tons, or thereabouts, represented the maximum strain which they had to bear, and for which they were calculated. But, as time went on, heavier and heavier engines were built, and there are express engines and tenders on the

Midland Railway, for example, now, which weigh together as much as 72 tons, and these will stand on a 60 ft. bridge. If we assume that the live load on such bridges amounted to 3 tons on the inch —the dead load being 2 tons—with 40 ton engines and tenders, then with 72 ton loads the strain will not be 5 tons, but 7.4 tons, which is perhaps not a safe load. Again, there are certain little bridges—the fall of any one of which would wreck a train—which, at the most, would not take in more than two pairs of wheels of an engine. The greatest weight they would have to bear thirty-five years ago would have been about 18 tons; now it will reach 25 to 28 tons. If the original strains due to the live load on the girders, mostly cast iron, was 10 cwt. per inch, it must now be 15.5 cwt., and like reasoning applies to abutments, and piers, and foundations. Not long since we had occasion to examine several small under bridges on a main line of railway. None of them was more than about 20 feet span. In every case we found the brickwork of the abutments shaken, and the landings on which the girders rested cracked. There was no immediate danger that such bridges would give way, but there was certainly no security that they would not. We have every reason to think that our large bridges are all safe, and the fall of the Tay Bridge will make them safer than ever, because they will be more carefully looked after. For example, it is stated that one eminent consulting engineer has ordered no less than 1000 tons of iron for wind ties and other devices for strengthening bridges, since the Tay Bridge fell. The true danger lies in the small under bridges, and it has been brought about by the age of the bridges and the augmented loads which they have to carry.

The danger is by no means confined to the girders. We could point out a bridge now, not ten miles from London, which has a span of about 18 feet. It consists of four cast iron girders resting on brick abutments. This bridge became shaky in the brickwork some years ago. It would have been desperately inconvenient to stop the traffic to rebuild it, and it was quite clear that settlement of the foundations was the cause of the trouble. The road which it spans is never used, so the bridge was propped with timbers extending across between the faces of the abutments and keeping them apart. It has been so propped now for a long time; but by and by this bridge will become very unsafe, if it is not unsafe now. All over the country may be found small bridges with the brickwork or stonework of the abutment faces shaken and split; arches may be seen split right through. We could cite one case where a viaduct is split from one end to the other. It has been tied together with transverse iron rods, but it is exceedingly doubtful if this viaduct is fit to be run over at high speeds by heavy trains. Every now and then we hear of a bridge tumbling down, as for example that at Llandulas, or that over the Wye, and it is urged that the fall was quite unexpected, and that the flood must have been abnormal or it would not have gone; the truth being all the time that there was nothing abnormal about the flood, but that a process of deterioration by wear and tear had begun from the first, and that this was immensely accelerated by doubling the strains, or nearly doubling them, for which the bridge was designed. The floods every winter did a little harm, and, at last, floods, vibration, and undue strains, all acting together to the same end, brought down the bridge. If its fall was not anticipated, that was because the engineers in charge did not realize the nature of the conditions under which it was worked. We do not mean to assert that floods may not arise which baffle all calculation, and carry away bridges like reeds; but such things are very rare, and when one flood carries away a railway bridge, it may be taken for granted that other floods had previously run past it and did it some injury by scouring the foundation or otherwise.

When Capt. Tyler inspected the Bristol and Exeter Railway a few years before it was handed over to the Great Western Company, he discovered and made out a list of 20,000 defects, each defect more or less dangerous. For the most part they were in the permanent way. On our best lines the permanent way is kept in very admirable condition, and it would be difficult in 100 miles of

such roads as the Great Western, Midland, or London and Northwestern to find a dozen serious defects. Is it quite certain that as much may be said of the bridges which carry this excellent permanent way? Some years ago we saw an iron bridge taken down and replaced by one of greater strength. When the removed bridge came to be taken to pieces, it told a story "enough," as an engineer present said, to "make one's flesh creep." Cracks and corrosion spoke volumes. It is the practice now to have bridges of all kinds examined almost daily; and we believe that on most lines the engineer-in-chief, accompanied by assistants, makes a tour of inspection once a year, and reports accordingly to his directors. Such examinations may have averted many accidents; some they have not averted. It might cost much money to carry out a special inspection, in which ballast would be taken up, foundations laid open, rivers carefully sounded and their bottoms bored, brickwork opened out, culverts stripped, and, in a word, a thorough examination made. But this we do know, that, unless something of the kind be done, accidents will occur, and they will occur with increasing frequentcy as weights and speeds increase and age steals by degrees on the bridges. Bridges originally well made do not tumble down for nothing, but the perfunctory inspection of a milesman can hardly be regarded as guaranteeing the security of such structures.

BIG BRIDGE CONSTRUCTION.

From "The Builder."

The rejection, by a Select Committee of the House of Commons, of the Bill for the construction of a slightly modified bridge over the Tay, affords a practical comment on the observations we have heretofore offered on the official inquiry into the causes of the disaster which befell the former structure. That two engineers, one Royal and one Civil, should have consented to carry on such an inquiry in the absence of the drawings of the bridge, and without making any such representation as to the absence of those drawings as might, at all events, have thrown the blame in the right quarter, was to us, at the time, inexplicable. We do not say that the Commissioners were bound to refuse to proceed with the inquiry in the absence of the drawings. But we did expect such an appeal to the Board of Trade in the first instance, and, failing redress, such a statement of the fact of this suppression of evidence in the report itself, as might have put the professional members of the Commission right with their own brethren. As it is, the shareholders have to pay the piper. Considering all that had been said, and all that had not been said, as to the responsibility of Colonel Hutchinson in respect of what was called the examination of the bridge on the part of the Board of Trade before opening the line over it for traffic, we do not see how Colonel Yolland could well have avoided reporting against the approval of a design which appears to have been adopted by the directors of the railway between their first and their second appearance before the committee—a design as to which the author admitted that "he had still much to verify." There is some confusion in the reports which we have read as to one point in his new design. From the evidence of Mr. Brunlees, it appeared as if brick piers on the existing foundations were proposed; but, on the other hand, it was stated by counsel that the piers were to be for a double width of line, while the bridge was to be, in the first instance, only for a single line. We fully agree with Colonel Yolland in the opinion that a single-line bridge should not be authorized. As to the question of brick or iron piers, it is a matter of design and of calculation, not to be settled offhand, or without due investigation. Still more important is the third requisition on which the Board of Trade has been advised to insist, namely, that the foundations should be entirely new. When demands of such a nature are made unexpectedly, before a committee, the pro-

moters of a bill are taken aback. It is possible that the addition of the proposed clauses would have the effect of at once doubling the cost of the bridge. At all events, this would take time to ascertain. Had the original design for the bridge been produced and discussed before the commission of inquiry, this company would have known what to expect. New demands could not have been raised at the eleventh hour; and the delay of a year, involving heavy expense, would have been saved to the company. As it is, however, the directors have only themselves to thank for an opposition which the suppression of the original plans rendered unavoidable, though it is to be regretted that it was not announced until the latest available moment.

The question of entirely new foundations is one of very great importance. Its turning up at this last moment affords a very striking proof of the penny-wisdom, which may prove to be pound-folly, of stinting the proper outlay for an important work. If the traffic which the Tay Bridge was to accommodate was worth the cost of building a bridge at all, even if a single line of way would in the first instance have been sufficient to accommodate the trains of the company, no person of prudence would have sanctioned the preparation of foundations that were insufficient to carry a double way. If the foundations had been put in for a bridge of the ordinary width, and if, above a certain height, the bridge had been in the first instance proceeded with for a single way alone, it is very possible that the overthrow would have been avoided. In any case, the contemplation that the need for a double line would arise at some future time ought never to have been omitted, nor should such a mode of obtaining foundations have been adopted as would have been certain to involve a very grave engineering difficulty whenever the case of widening came to be carried out.

It is well to give full attention to this part of the case, because it points to something nearer home than Dundee. In the various plans which have from time to time been ventilated as to the widening of London Bridge, the advocates appear to have closed their eyes to the nature of the foundations obtained by Rennie. This great engineer was compelled by the City authorities to build the noble monument in question in a spot which he considered not the fittest for the purpose. The true site of the bridge was abandoned for the sake of saving the expense of a temporary bridge. As far as the means at the command of the science of his day went, Rennie made the best of his design. But it was touch and go. In fact, it was "go" for some fourteen inches, and though the movement of the abutment was arrested, and the bridge has ever since been stable, there can be no certitude as to the anticipation how soon the steady action of the river in deepening its bed may set the bridge again on the move, and we think there is very little room to doubt that any tinkering of the superstructure would very rapidly have that effect.

All builders know how ticklish a thing it is to build a new wall as a continuation of an old one into which it is to be bonded. And if this be the case in the open air, on the side of a house, or on any line of plain surface, how is the difficulty increased if the junction has to be effected thirty feet under water, in an estuary or tidal river? This task, which we think it would probably prove impossible to accomplish on London Bridge without some mishap, is not an easy one to effect in the River Tay. But the putting in of brick foundations for a double line would require such a junction of new and of old work. We think that it may be very seriously questioned whether it would not prove safer, and ultimately cheaper, to build a new bridge *in toto*, and to remove all the piers of the old bridge, than to undertake the task of widening the piers of the latter. At all events, we hold it tolerably certain that there are no grounds for any confident expectation to the contrary. It might be possible to coffer-dam round the existing piers, to excavate and lay wider foundations, and to carry up the whole as a sound piece of workmanship; but with evidence before the committee that it may be necessary to protect the bottom of the river from scour "by means of stone," in fact, to pave or pitch the bottom of the Tay, we feel sure that the very best and most deliberate advice

ought to be secured before making any such attempt.

The actual position of the Tay Bridge is such as to point to the need of an exhaustive inquiry into the theory of bridges of large span. At the present time the width of the span into which a bridge may be divided—and we may say the same with regard to the roof of a station, or of any great area—depends pretty much upon the taste of the engineer. The question of level, in the case, at all events, of the bridge, is here one of primary importance. A balance has to be struck between the cost of pier and that of arch; between the cost of numerous piers, and that of arches or girders over wide spans. No definite relation can be laid down as normal between the two estimates of cost, because the cost of the piers differs to an extraordinary extent in different cases. Thus a span which it might be altogether extravagant to use in the case of a wide flat valley, might prove to be economical in the case of a deep ravine. If any approach to a general formula of proportion is to be obtained, it must include an expression for the height of the piers, and another expression for the anticipated costliness, in the matter of obtaining foundations.

It is instructive, as giving some measure of the progress made by the engineer during the past sixty years, to compare the dimensions of Old London Bridge, according to the survey of it made by Mr. Giles, in 1820, by order of the Committee of the Bridge Lands, with some of the latest erections of large spans, both in this country and the United States. The width of the river between the abutments of London Bridge, according to the survey quoted, was 931 ft. Of this width no less than 406 ft. 10 inches, or above 42 per cent., was occupied by the piers. But a further obstacle to the flow of the river was offered by the starlings, or pile-work protections, to prevent the piers from being under-cut by the current, which amounted to 293 ft. 5 in. This reduced the water-way, at low water, to 230 ft. 11 inches, or rather less than one-fourth of the normal width of the river. The consequence of this contraction was to produce a row of waterfalls through the arches of the bridge, in which the river fell 2 ft. 1 inch at neap tides, and 4 ft. 4 inches at springs; an extreme fall of 5 ft 7 inches having been noted during the occurrence of a highland flood, falling on a spring-tide ebb.

In contrast to this cumbrous and clumsy structure, we may cite the elaborate calculations brought by Professor Clericetti, of Milan, before the Institution of Civil Engineers, and published in vol. lx. of the Minutes of Proceedings of that Institution. The result, in two lines, is, that a girder can be constructed which would bear its own weight for a span of 900 meters, and that by the addition of inclined steel cables, fixed to towers rising 90 meters above the girders, a span of 1,500 meters might be obtained. The pull upon the cable, in this case, is taken at 20 kilogrammes for each square millimeter of cross section, or rather more than 13 tons per square inch. M. Max am Ende calculates the limiting span of a straight girder, with struts and diagonal ties, with 5 tons strain on the square inch, at 2,870 ft.; that for a straight girder, with diagonal struts and diagonal ties, at 4,000 ft. for iron, and 6,000 ft. for steel, with a strain of 7½ tons per inch. For a parabolic bowstring girder, the limiting span is given as 3,000 ft., the corresponding depth of the girder being 1,830 ft. For the parabolic fish girder, this gentleman proposes a limiting span of 4,200 ft., with a depth of 3,600 ft., in iron, and a span of 6,300 ft., with a depth of 5,400 ft., in steel. These are purely theoretical figures, and take into account simply the force of gravity.

As to most of this, however, the practical builder will be content to allow it to remain in the cloudy limbo of algebraical theory. What is more to the point is to inquire of what spans bridges have been actually constructed. We can obtain some valuable information on this subject from a paper by Thomas Curtis Clarke, M. Inst. C.E., which was read before the Institution of Civil Engineers on the 21st of May, 1878. But it is very remarkable, as illustrating how far we yet are from arriving at any normal rules, such as we before indicated as desirable, for the proportion between width of span and number of piers, that, in the 21 columns in which Mr. Clarke tabulates the information of which we

are about to cite a portion, no mention is made of the height of the platform of the bridge above the water which it crosses.

The width of span, then, which has been obtained in the case of sixteen important tubular and girder bridges, constructed of iron, up to the year 1877, are as follows:

Where built.	Span.	Engineer.
1. Susquehanna Riv.	307	Phœnix Bridge Co.
2. Ohio River	319	J. H. Linville
3. St. Lawrence River	330	Rob't Stephenson
4. Ohio (Parkersberg)	342	J. H. Linville
5. Rhine, Mayence	345	Gerber
6. Ohio (Louisville)	368	Albert Fink
7. Kentucky River.	375	C. S. Smith
8. Ohio (Louisville)	396	Albert Fink
9. Vistula (Dirschau)	397	Lentze
10. Conway, N. Wales	400	Rob't Stephenson
11. Ohio (Cincinnati)	415	J. H. Linville
12. Inn (Passau)	420	
13. Saltash	455	I. K. Brunel
14. Menai Straits	460	Rob't Stephenson
15. Lek, Holland	492	G. Van Diesen
16. Ohio (Cincinnati)	518	J. H. Linville

The figures merely indicate the width in feet of the longest span in each of the bridges cited. To these works should be added the suspension railway bridge over the Niagara river, immediately above the Falls, which was opened for traffic in March, 1855. The span of this bridge is 822 ft. 6 inches. The height of the platform, which carries three lines of rails, of the respective gauges of 3 ft. 6 inches, 4 ft. 8½ inches, and 5 ft. 6 inches, above the river, is 250 ft. Below the railway platform is suspended a second platform, for common road vehicles, The bridge is supported by four wire cables, of 10 inches diameter, each containing 3,640 wires of No. 9, B. W. G. The weight of the superstructure is 750 tons. The supporting strength of the cables is estimated at 7,000 tons. The bridge was designed and constructed by the late Mr. J. A. Roebling, the engineer in chief, who was also a manufacturer of wire ropes. The cost was about 500,000 dollars, or a little over £152 per foot of span.

Of the bridges in the table, those built by Mr. Stephenson over the Conway, in 1848, the Menai Straits, in 1850, and the St. Lawrence, in 1859, are all tubular girders, through which the trains run. The bridges numbered 2, 6, 8, have the top chords cast, the rest of the girders being of rolled iron. The girders are quandrangular, with pin connections. Numbers 1, 4, 7, 9, 12, 15 and 16, are all made of rolled iron. The Saltash Bridge, built by Mr. Brunel in 1859, crosses the river Tamar, about three miles north of Plymouth, at a place where the river narrows to about 1,100 ft. wide, and has a depth of 70 ft. It was at first proposed that this bridge should consist of seven openings, one of 250 ft. and six of 100 ft. each. But the Admiralty insisted that there should be only four spans, two of 300, and two of 200 ft. each, with straight soffits, and a clear headway of 100 ft. above high water. After a very careful and minute investigation of the bed of the river, made by 175 borings, carried on by aid of a wrought-iron cylinder 6 ft. diameter, and 85 ft. long, which was slung between two gun-brigs, and pitched at thirty-five different places on the river, Mr. Brunel decided upon adopting two main spans of 455 ft. each, supported on a masonry pier. For the construction of this pier a wrought-iron cylinder, 37 ft. in diameter and 90 ft. in length, was sunk through the mud at the bottom of the river to the solid rock. The total length of the bridge, including the adjoining land-openings, is 2,280 ft. It consists, besides the two main spans, of two openings of 93 ft., two of 83 ft. 6 inches, two 78 ft., two of 72 ft. 6 inches, and nine of 69 ft. 6 inches each. The central column, of solid masonry, 35 ft. in diameter, is 96 ft. in height from the rock foundation to above high-water mark. Upon this are placed four octagonal columns of cast iron, 10 ft. in diameter, carried up to the level of the roadway, which is 100 ft. above high-water mark. Holding-down lewis bolts were let into the solid rock on which this pier was built, with iron bars built into the masonry. A description of the center pier of this noble bridge, by Mr. R. P. Brereton, M. Inst. C.E., will be found in vol. xxi. of the Minutes of Proceedings of the Institution of Civil Engineers.

In the course of the discussion on Mr. Clarke's paper, from which we have cited the spans of sixteen large bridges, Mr. Barlow compared the efficiency and structural merit of the several designs,

according to a method proposed by Professor Rankine, which consists in ascertaining the limiting spans attainable on each system. The bridges in question may be arranged in four classes, viz: (1) quadrangular girders, with pin-connections; (2) the Saltash Bridge, which Mr. Clarke calls a lenticular girder; (3) lattice bridges; and (4) tubular bridges. Of these, the six examples of the first kind have an average limiting span of 900 ft., the several cases ranging from 852 ft. to 982 ft. Mr. Brunel's bridge, though of comparatively an early date, has a limiting span of rather more than 900 ft. In the lattice bridges, the waste of metal amounts to from 40 to 46 per cent., as compared with the former structures. In the tubular bridges it is still more; but it must be remembered that these were the first efforts to introduce iron in large spans in railway bridges.

In looking at the large amount of valuable information that may be gleaned from many of the sixty volumes of the Minutes of the Proceedings of the Institution of Civil Engineers, we are struck with the absence of any attempt to show such a comparative view of the cost of these great structures as would be of service in framing general rules for the guidance of the bridge builder.

The remarks which we have just quoted go in the right direction, but they only go a little way in that direction. Mr. Douglas Fox, in the discussion on Mr. Clarke's paper, gave the counsel to avoid large spans altogether if possible, because, if a pier could be introduced, even though the cost were the same, it would be a great advantage. We are disposed to agree with the recommendation. But what we want is, not to have it offered as an opinion, but to have the facts so clearly brought out as to allow them to speak for themselves. "The larger the span, the greater the risk in erection, and the greater the cost in maintenance." That, moreover, may be true, but again we wish for proof. Again, the fact that certain elements of strength are required to increase, not as the span, but as the square of the span, is one that needs being brought fully out—so as to show in what manner, other things being equal, the cost of one opening of 200 ft. span compares with that of two openings of 100 ft. span each—taking the girders alone; so that allowance may be made for the piers according to the height of the structure. We find no attempt to bring this before the professional world, and we feel very sure that architects, engineers, and builders will have reason for gratitude to the writer who shall put into available form the large mass of experience which has been attained on this subject.

Mr. Clarke, in his reply, made some observations which show that American engineers have given due attention to a subject on which it must be admitted that English engineers have not of late exhibited the most profound knowledge. "A bridge," said this gentleman (whose address is given as in New York), "is a complex structure. It has to bear not only the force of gravity, but the side pressure of the wind. It has been said that it was a simple matter to provide against the force of wind, but that was really the most difficult and complicated part of the problem. The most economical height possible had to be used to resist the force of gravity; but then the side pressure prevented the use of an economical height; consequently, the bridge, when it was finished, was a compromise between the results of two forces That was why the long-span bridges were comparatively not so high as those of shorter span. In spans of less than 200 ft. the proportion of height to span was 1-5th or 1-6th." When we find that this outcome of American practice was brought before the Institution of Civil Engineers in May, 1878, Mr. W. H. Barlow being in the chair, we cannot avoid referring to the opinion we felt bound to express (*ante*, p. 39) with regard to the report of Messrs. Hawkshaw, Bidder, Harrison, and Barlow, as to the adoption of 10 lbs. as side pressure on the Forth and Tay bridges. In this country, when the first bridges of wide span were designed by Mr. Stephenson and Mr. Brunel, the question of wind pressure, although duly considered by those experienced engineers, had not assumed the importance which attached to it in the opinion of the designers of the bridges on the American pattern. We have on record references to investigations as to the force of the wind on the Menai bridge, as well as to the wind

action on the suspension bridge of Telford over the same Straits. But with regard to the tubular girders we might almost as well have inquired whether a storm of wind could blow down the walls of Conway Castle, as whether it could shift or overthrow the great tubes. And in the case of the Saltash bridge, where the resistance offered to the side pressure of the wind was comparatively so small, we have seen what were the ponderous dimensions of the central pier. Those were the works of the fathers of our railway system; and whatever may be said of the advance of science since, it is certain that Stephenson and Brunel did not build works which it was unsafe to cross in a storm, were it the fiercest that ever blew in our island. What we feel to be so lamentable—we might use a stronger word—is the comparison of the evidence and arguments offered as to the Tay bridge with the practice of our two great engineers on the one hand, and with the study, as well the practice, of the engineers of the United States on the other. In the discussion to which we have referred, one engineer, Mr. E. W. Young, said that "in every bridge designed by him 40 lbs. wind pressure per square foot had been allowed, and security obtained." "The difficulty in designing girders of very long span is to get width enough to resist wind pressure," observes Mr. Clarke. It would be well if every student who reads the reports made to the Board of Trade by Mr. Barlow and Colonel Yolland, as well as that of Mr. Rothery, were also to read with attention the debate from which we have made extracts. It will strike them, we think, that the degree of knowledge of wind pressure that has been brought to bear on the subject of the Tay bridge by all those who have given advice or evidence on the subject, is very far below that which is common to the engineers of America, of Germany and of France.

THE MAXIMUM AVAILABLE WORK OF GALVANIC BATTERIES.

Translated from La Lumiére Electrique.

It may be asserted, without fear of contradiction, that half of the electrical inventions which have been produced within thirty years have been related to electric motors. The failure of these inventions has been due to several causes of which the two principal ones are:

1st. The difficulty of constructing an electro-motor capable of utilizing all the current furnished by a given pile.

2nd. The absolute ignorance, of the greater part of the inventors, of the quantity of work produced by a pile; a quantity perfectly determinate by the laws which govern electro-chemical reactions, and a quantity, moreover, which can never be exceeded.

The inventors of electric motors, working under the conditions in which they generally place themselves, are closely related to the perpetual motion hunters, or to the inventors who seek to drive a locomotive by employing a coffee pot for a boiler.

We propose, in this article, to examine briefly the maximum work produced by the batteries most commonly employed, and to show within what limit this work is produced, so as to prevent stumbling against impossibilities, and to abolish deceptions which are yet too numerous.

We may consider a battery as a veritable *electrical boiler*, furnishing a certain *quantity* of electrical current per second, just as a steam boiler affords a certain *volume* of vapor. This vapor is furnished by the boiler at a certain *pressure;* in like manner, the electricity furnished by the battery possesses a certain *tension* or *electromotive force.*

Take, for instance, one hundred elements of some battery as Leclanché.

We can group these elements in different ways, but we will consider only the two extreme cases:

1st. *Arranged for intensity.*—Connecting the zinc of the first cup to the carbon of the second, the zinc of the

second to the carbon of the third, and so on to the end of the series.

This *intensity* grouping yields an electromotive force one hundred times as great as that of a single cup, but presents at the same time an internal resistance one hundred times as great as a single cup.

2nd. *Arranged for quantity.*—This is accomplished by uniting all the zinc elements to one conducting wire, and all the carbons to the other. In this case the electromotive force is only that of a single element, but the internal resistance has been divided by one hundred, a condition which augments the quantity of the current without increasing the tension. In the first case we have small volume or quantity, but great pressure or tension.

In the second case the tension is feeble but the quantity is considerable. Theory establishes that if in each case the *external* resistance is equal to the *internal*, the work is at a maximum.

The expression for maximum work is very simply stated by the formula of Joule:

$$W=\frac{Q^2R}{9.81}\text{ kilogrammeters.}$$

In which, W is the work, Q is the intensity or quantity of the current expressed in Webers, R the external resistance (equal to the internal) expressed in Ohms. The value of Q is deduced by Ohms formula:

$$Q=\frac{E}{R}$$

R being the total resistance of the circuit, and E the electromotive force expressed in Volts.

Now, in a battery of one hundred Leclanché cells mounted for tension, we have for the electromotive force of each cell (of the new pattern) 1.5 Volts and an internal resistance of 1.13 Ohms. This gives for the value of Q

$$Q=\frac{150}{226}=0.66\text{ Webers.}$$

The available work becomes

$$W=\frac{0.66^2\times 113}{9.81}=5.02\text{ kilogrammeters.}$$

According to this, if we suppose a motor theoretically perfect, and a battery to have a constant resistance and to be absolutely unpolarizable, a condition never realized, we see that 100 Leclanché cells can never afford quite the work of one man (6 kilogrammeters).

These calculations, applied to some common forms of battery, yield the following results:

Kind of Battery.	E Electromotive force in Volts.	R Internal resistance in Ohms.	Q Intensity in Webers.	W Available work of circuit in kilogrammeters.
Daniell Battery of high resistance	1.07	10.	0.0535	0.292
Daniell Battery of feeble resist'ce	1.07	0.6	0.89	4.85
Leclanché, new model........	1.50	1.13	0.66	5.02
Bunsen, medium	2.00	0.41	2.44	25.88
Bichromate, Boudet model...	2.09	0.22	4.75	50.6
Bunsen, Ruhmkorff model...	2.00	0.12	8.33	84.88

These figures show that galvanic batteries considered as sources of motive power can only give satisfactory results when applied to light work requiring a small number of kilogrammeters. The last line of the table shows that more than 100 Bunsen cups of the Ruhmkorff model are necessary to afford a work equal to a one horse-power steam engine.

But, if we take account of the polarization of the plates, the increase of internal resistance, the loss due to imperfect contacts, the hurtful resistances of the conductors, etc., etc., we shall better represent the inferiority of the galvanic pile as an industrial source of motive power.

If, now, we take for the sake of comparison, the figures representing the performance of a Gramme machine of the workshop pattern, we shall see what economy can result from its use in producing powerful currents of electricity.

A Gramme machine of the A pattern, having an interior resistance of 4.58 Ohms, and acting through an external circuit of 4 Ohms, develops an electric current of which the electromotive force is 158.5 Volts, and the intensity 17.5 Webers, representing about four horse-power.

If we wish to replace a similar machine by Bunsen cups of average size, it will be necessary to arrange them in series of 79 for tension to obtain the required electromotive force, and 7 for quantity to have the proper resistance, which requires 553 cups. Such figures dispense with comments.

If we consider the batteries with reference to telegraphic uses, the results look entirely different. The external resistances being very great, compared with the internal, there results a current of low intensity, varying from 2 to 15 milli-webers. Such a current, even upon a circuit of high resistance, represents an insignificant amount of work; the consumption of zinc is small, and the polarization is slight.

It results, then, from these considerations, that galvanic batteries are, as sources of electricity, inapplicable for motive power except in special cases, and their use is more profitably restricted to light and delicate apparatus, such as telegraphs, clocks and the like.

The working of a battery is best when it has the least mechanical work to accomplish. This fact should not be ignored by inventors who seek to obtain from this electric source more than it can give.

ON THE PRESERVATION OF THE ANCIENT BRIDGES IN THE REGULATION OF THE COURSE OF THE TIBER.

By A. VESCOVALI.

Translated from Il Politecnico for "Abstracts" of the Institution of Civil Engineers.

Signor Vescovali investigates the problem whether it is necessary, for the protection of Rome from inundation, to demolish or widen the ancient bridges over the Tiber. He regards this question as important, on the one hand, from the point of view of the archæologist; on the other hand, from that of the hydraulic engineeer. If the rigid rule be followed for the execution of the works now in progress to widen the bed of the river from the actual width of 60 or 80 meters, to the given minimum width of 100 meters, it will be necessary either to demolish or to add new arches to the existing bridges. But if the object be so to lower the bed of the river as to restrain the floods within the quay walls, this demolition is not unavoidable.

The ancient bridges of Rome are:—1. Ponte Molle; 2. Ponte S. Angelo; 3. Ponte Sisto; 4. Ponte Cestio (on the right), and, 5, Ponte Fabricio (on the left) of the Isola Tiberina. This list does not include the Suspension bridge, on the site of the Pons Æmilius; the ruins of the Sublician bridge, about 400 yards lower down the Tiber, or those of the Pons Triumphalis, at the bend of the river, west of S. Angelo. The nature of the bed of the river at the points crossed by these five bridges is described as "excavable" under the Ponte S. Angelo, and under the right-hand arch of the Ponte Fabricio. Under the other arches, the bed of the river is covered with the ruins of former bridges, and perhaps with brick platforms of masonry, and is described as "inattackable." The levels of the bed of the river at the five points named are, respectively, 17.16 feet, 12.17 feet, 2.97 feet, 11.94 feet, 8.71 feet, 3.59 feet, and 3.15 feet above the zero of the Ripetta fluviometer, which is 3.17 feet above the mean level of the sea* The third and fourth of these figures apply respectively to the two middle, and the two lateral arches of the Ponte Sisto; and the last two refer to the right-hand and the left-hand arches of the Ponte Fabricio. The channels under the lateral arches of the Ponte Sisto have, however, been recently excavated to a depth of 2.64 feet above the fluviometer zero.

The spans and areas of the apertures of these bridges are given in meters, as it will be more convenient for comparison with the volume of the river than if they are reduced to English feet. They are as follows:

*It is considered that the floods now amount to the volume of 3,000 metric tons per second, the low water volume of the Tiber being 100 metric tons per second. —F. R. C.

	Spans. Meters.	Areas. Meters.
Ponte Molle	71.50	641.52
Ponte S. Angelo	50.20	751.37
Ponte Sisto	69.40	739.70
Ponti Cestio e Fabricio, together	59.20	913.17

It is estimated by Signor Vescovali that it is possible to enlarge the waterway of the Ponte S. Angelo, by deepening the bottom of the channel to 1,084.87 square meters; and that of the two last-named bridges taken together, to 995.05 square meters. The waterway of the Ponte Sisto has been enlarged, by the work now in progress, to an area of 839 square meters, by deepening the channel under the lateral arches by 2.92 meters. Thus the Ponte S. Angelo, which has the least width of waterway of any of the bridges, has the greatest sectional opening in times of flood.

Signor Vescovali then argues that the Ponte S. Angelo does not cause any regurgitation of the water of the river; and states that the level of the water on the right bank of the Tiber, near S. Spirito, is sensibly higher than that on the left in time of flood; a fact for which the rapid curve in the channel accounts. In the flood of October 31, 1873, which rose 13.73 meters above the fluviometer zero, there was a difference of 25 centimeters in the level of the water on the opposite banks.

Signor Vescovali mentions the existence of a mass of ruin which forms a bar across the river between the Palazzo Altoviti and S. Spirito, the crest of which rises nearly to the low-water level at that point, or eight meters above the bottom of the channel under the Ponte S. Angelo.* He considers that it is this bar, and not the bridge, which arrests the flow of the Tiber in this locality; and states that, in the flood of 1870, when the arches of the bridges were entirely under water, the river stood at the same level above and below the bridge of S. Angelo.

The author is, therefore, of opinion that the first thing requisite for the proper regulation of the channel of the Tiber is the removal of those masses of ruin which prevent the river from deepening its own channel in time of flood. He states it to be a canon of hydraulic science, that in all rivers of which the banks are protected from erosion, and the bottom is formed of movable material, the bed becomes lowered by the force of the current in floods, and gradually fills up to its former level in that low-water state, to describe which there is no good equivalent for the Italian word "magra" (feeble). With regard to the Tiber, from the site of the ancient Pons Sublicius to the sea, the bed is composed of material removable by a rapid current. Above this point, Signor Vescovali is of opinion that the actual height of the water is artificially kept up by the ruins, which prevent the scour from having a proper effect on the bed of the river. He states that when the tubular piles for the bridge for the Civita Vecchia railway were driven, fragments of pottery, ancient lamps, and numerous *stili*, of bone and ivory (with which the Romans were accustomed to write on their waxed tablets), were found in a stratum 1 foot deep which crosses the channel of the river at a depth of about 2 meters below the zero of the Ripetta fluviometer. He considers that the stratum indicates the ancient level of the bed of the Tiber, and that in time of flood the level was normally excavated by the current down to a depth of 3 meters below the present bottom of the Ponte Cestio, and 2 meters below that at the Ponti Fabricio e Sisto.

Signor Vescovali, however, is of opinion that the ancient bridges over the Tiber were founded on platforms of masonry built across the bed of the river, which was probably partially diverted during the progress of the works. He gives reasons for this view, but insists on the necesity of ascertaining the fact, before proceeding with the costly works now in progress. He considers it probable that these platforms now exist, at a depth sufficient to allow of ample water-way being kept open through the bridges, if the ruins that encumber the bed of the river are removed. His opinion is that the now existing width of 50.20 meters at the Ponte S. Angelo will be ample to carry off the water that comes through the newly-regulated channel 100 meters wide, in consequence of the greater depth that the scour will then produce beneath the archways.

Signor Vescovali cites the example of the engineers Lombardini and Brighenti,

*Which would be down to the mean level of the sea.

who, in order to reduce the heights attained by the floods of the Arno in Florence, proposed, not the rebuilding of the bridges, but the removal of the masonry platform on which they stand, in order to allow of the excavating action of the scour of the river. He points out however, the danger of undermining the piers of a bridge by such an operation; and remarks that the nature of the soil through which the Tiber flows is such as to have rendered necessary, in the recent construction of bridges, to cross its bed, piling to a depth of nearly 40 feet (12 meters) below the level of low water. Thus, while still in ignorance of the exact system on which the ancient bridges over the Tiber were built, Signor Vescovali holds that the bed of the river through Rome has been notably raised.

The council of Public Works propose a clearing of the bed of the river, limited to a level of 1.50 meter above the zero of the fluviometer at the Ripetta, from which point the profile is to be horizontal as far as the Ponte Molle, going up stream, and to fall with the gradient of 0.40 per kilometer towards the sea. According to this plan, the bed of the river at Mormorata (below the site of the ancient Sublician Bridge) will be 0.10 meter above the zero of the fluviometer. At the two island bridges it will be 0.29 meter above, and at the Ponte Sisto, 0.50 meter above that fixed point. Signor Vescovali urges that the depth requisite below the bridges ought to be at least 3 meters below the zero of the fluviometer. He holds that if the channel is clear to this depth —which is the level of the platform of the Ponte S. Angelo, and of the right arch of the Ponte Fabricio—ample waterway will be secured for the river without demolition or enlargement of the bridges. He is of opinion that the course of the channel should be regulated, according to the plan of Signor Cesarini, from the Ponte Molle to the Canal of Fiumicino; and that in consequence the low-water level would be reduced 4 meters at Ripetta; that a depth of 5 meters would be retained in times of drought; that the level of the floods would be reduced from 4 to 5 meters below that attained in 1870; that the level of the subterranean waters in Rome would be lowered by 4 meters; and that navigation would be practicable from the sea to the city of Rome.

NOTE.—As the zero of the Ripetta fluviometer is only 0.97 meter above the mean level of the sea, the bottom of the channel of the Tiber in Rome, according to the above suggestion, would be 2.03 meters below sea level. Referring to the account given (Minutes of Proceedings Inst. C. E., vol. lvii., p. 360), of the gradual depression of the eastern coast of Italy, the question arises whether a similar movement in the valley of the Tiber may not have occurred, in which case the increased damage caused by floods would become readily intelligible.

ON THE LAW OF FATIGUE IN THE WORK DONE BY MEN OR ANIMALS.

From "Nature."

The Rev. Dr. Haughton, of Trinity College, Dublin, has recently brought to a conclusion a series of papers on Animal Mechanics published in the *Proceedings* of the Royal Society. The ninth of these papers was appointed the Croonian Lecture for the present year, and the tenth paper closes the series.

The most important subject involved in these papers is the experimental determination of the law that regulates fatigue in men and animals, when work is done so as to bring on fatigue.

Many writers, such as Bouguer, Euler and others, have laid down mathematical formula, connecting the force overcome with the volocity of the movement; but these theoretical speculations have never received the assent of practical engineers.

Venturoli points out a method of observations and experiments which would serve to determine the form of the function which expresses the force in terms of the velocity, after which a few carefully planned experiments would determine the constant coefficients; and he adds that "such a discovery would be of the greatest usefulness to the science of mechanics, upon which it depends, how to employ, to the greatest possible advantage, the force of animal agents."

Dr. Haughton believes that he has found the proper form of this function, by means of experiments, and sums it up in what he calls the *Law of Fatigue*, which he thus expresses:

The product of the total work done by the rate of work is constant, at the time when fatigue stops the work.

If W denote the total work done, the law of fatigue gives us—

$$W\frac{dW}{dt}=\text{const.},$$

or

$$\frac{W^2}{T}=\text{const.} \quad . \quad . \quad . \quad . \quad (1)$$

The experiments made by Dr. Haughton, from 1875 to 1880, consisted chiefly in lifting or holding various weights by means of the arms; the law of fatigue giving, in each case, an appropriate equation, with which the results of the experiments were compared. When the experiments consisted in raising weights on the outstretched arms, at fixed rates, the law of fatigue gave the following expression—

$$(w+a)^2n=A \quad . \quad . \quad . \quad . \quad (2)$$

where w, n, are the weight held in the hand, and the number of times it is lifted, A is a constant to be determined by experiment, and a another constant depending on the weight of the limb and its appendages.

The equation (2) represents a cubical hyperbola.

The *useful work* done is represented by the equation—

$$wn=\frac{Aw}{(w+a)^2} \quad . \quad . \quad . \quad (3)$$

This denotes a cuspidal cubic, and the *useful* work is a maximum, when $w=a$, or the weight used is equal to the constant depending on the weight of the limb and its appendages.

When the weights were lowered as well as raised at fixed rates, and no rest at all permitted, the law of fatigue became—

$$\frac{n(1+\beta^2t^2)}{t}=A \quad . \quad . \quad . \quad . \quad (4)$$

where n, t, are the number and time of lift, A is a constant depending on experiment, and β is a constant involving the time of lift (τ) at which the *maximum* work is done.

Equation (4) denotes a cuspidal cubic.

When the weights are held on the palms of the outstretched hands, until the experiment is stopped by fatigue, the law becomes—

$$(w+a)^2t=A \quad . \quad . \quad . \quad . \quad (5)$$

where t is the whole time of holding out.

This equation denotes a cubical hyperbola.

The *Law of Fatigue* seems, in itself, probable enough, but of course its real value depends on its agreement with the results of experiment.

If W denote the total work done and R the rate of work, the law becomes, simply—

$$W\times R=\text{const.} \quad . \quad . \quad . \quad (6)$$

If different limbs, or animals, were used, each working in its own way, and under its own conditions, the *Law of Fatigue* would become—

$$WR=W_1R_1+W_2R_2+W_3R_3+\&c. \quad . \quad . \quad (7)$$

and the problem for the engineer would be, so to arrange the work and rate of work of each agent employed, as to make the *useful work* a maximum, the work both useful and not *useful*, in all its parts, remaining subject to the conditions imposed by equation (7).

In using equation (5) in his concluding paper, detailing the results of experiments made on Dr. Alexander Macalister, Dr. Haughton treats a as an unknown quantity, and finds from all the observations its most probable value to be—

$$a=5.68 \text{ lbs.}$$

This result was compared with that of direct measurements made on Dr. Macalister himself, and indirect measurements made on the dead subject, from all of which Dr. Haughton concluded the value of a to be—

$$a=5.56 \text{ lbs.} \pm 0.125 \text{ (possible error).}$$

This result agrees closely with that calculated from the law of fatigue.

It should be added that a proposal was made by Dr. Houghton to Dr. Macalister to make the experiment conclusive by direct amputation of his scapula, a course which he, unreasonably, objected to, as he draws the line of "vivisection" at frogs.

DETERIORATION OF IRON IN MARINE STEAM BOILERS.*

By JOHN A. TOBIN, Engineer Corps United States Navy.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THERE is, perhaps, no single subject within the wide range of steam engineering which has invited the earnest consideration of the engineer and chemist more than that of the deterioration of iron in boilers.

Many wild theories and hasty conclusions have been published by those who, apparently, could not have given the subject much thought, and many may have been misled thereby, as to the true cause.

In this paper I do not pretend to advance any new theories, but will confine myself to a few facts gleaned from experience, and call attention to some others bearing upon the subject, which will be found in several of the leading engineering journals, and in the Boiler Committee Reports of the English Government.

I will briefly mention the circumstances connected with an extraordinary case in the bottom sheets of the steam drums of the United States Steamer Swatara, the first sloop of war fitted with a compound surface condensing engine, with seamless brass condenser tubes tinned on both sides. Ten cylindrical boilers furnish steam to the engine through copper steam pipes. Situated in the upper spandrels, between each pair of boilers, are the steam drums—thickness of shell $\frac{3}{8}$ inch. The drums are connected with the boilers by untinned copper pipes. After two and a half years service, a leak developed in the bottom of one of the drums; its condition was examined and found to be badly deteriorated. This fact prompted an examination of the remaining drums, and they were found to be in a similar condition. As high as the water from condensation had risen, corrosion was found to have been very destructive, particularly along the bottom, which was covered with a dark greasy sludge mixed with a noticeable quantity of oxide of iron. Not till each defective sheet was cut out and passed through the rolls were the different kinds of corrosion clearly defined, such as pitting and confluent honeycombing, from the merest impressions to a depth equal to the thickness of the sheet. The wrought iron bolt heads, which held the main drain valves, were completely wasted, while the rivet heads adjacent were simply coated with oxide of iron.

In the month of December, 1876, I sent to Professor Wm. Ripley Nichols, Professor of Chemistry in the Massachusetts Institute of Technology, a small sample of deposit from one of the drums, together with a specimen of one of the defective sheets, and all the particulars that would have any bearing upon the case; although, at the time, busily engaged with school work, he was good enough to find time to examine the specimens, but not as thoroughly as he would have liked. In the sample of deposit, he reports not finding any copper, but upon the examination of the specimen of plate he states as follows:

"I find in places a quantity of a greasy deposit containing copper, apparently in combination with fatty acids. I have not had time to prove in just what form of combination the copper is. I dare say there are several compounds: ollate, stearate, and palmitate. Whether there is any acetate of copper I cannot say, but from the greasy deposit I obtained good tests for butyric acid, so that there is some butyrate of copper no doubt. The copper compounds in contact with the metallic iron would be reduced to metallic copper, and a corresponding amount of iron would be oxydized, and then there would be a galvanic action established between the particles of copper deposited and the iron of the plate. The inner surface of the drums is no doubt continually wet, and on account of spray carried from the boilers the water is charged more or less with saline matter, as I inferred

* Read before the Society of Arts, Mass. Institute of Technology.

from examination of the deposit, this was mainly, although not wholly, hydrated oxide of iron. The presence of the saline solution would favor the galvanic action if the copper were once set free. The greasy matter would, however, protect the copper compounds from decomposition, and it is not, therefore, a matter of surprise that copper should be found in combination. I found, however, by examining the scale on the plate, that there were actually *metallic particles* of copper present, and it seemed to me that this alone might account for the effects which were observed."

In reply to certain questions he further states: "Olive oil is a mixture of three chemical compounds: olein and palmitin, which make up the bulk of the oil, and stearin, which is present in small amounts only. These three compounds, which are neutral bodies, are called in chemical langauge as follows: Olein is oleate of glyceryl; palmitin is palmitate of glyceryl; stearin is stearate of glyceryl. As nitric acid is related to nitrate of soda, and as sulphuric acid is related to sulphate of lime, in the same sense, oleic acid is related to olein and palmitic acid to palmitin. If olive oil (call it a mixture of olein and palmitin) be heated with hydrate of sodium, there is formed oleate and palmitate of soda—which we call soap—and hydrate of glyceryl, which we call glycerine. If carbonate of soda be used, the soap formed is just the same, also the glycerine, while the carbonic acid escapes. Almost all the natural fats are constituted similarly to olive oil; some contain more stearin, such as beef fat, for example, and all can be saponified by alkalies. The fats and oils may also be decomposed by superheated steam, and in the manufacture of the so-called stearine candles (which are really made of a mixture of stearic and palmitic acids), this process is used on a large scale. Under these circumstances, from the stearin and a portion of the water, are formed stearic acid and glycerine. From the palmitin and water are formed palmitic acid and glycerine, and from olein and water there are formed oleic acid and glycerine. The temperature of the steam in the cylinders is no doubt sufficient to bring about partial decomposition of the oil used for lubricating, and attention has been recently called (*Iron*, Sept. 23, 1876), to the enlargement of the cylinders, caused by such decomposition of the grease, a fact which has been previously noticed and noted. In your case, however, it does not seem to be simply the direct action of the acids upon the iron, although this probably plays a part, but it would appear that the acids attack the copper, forming oleate and palmitate of copper, and then, by the contact of these compounds with the iron, there are formed the corresponding iron compounds, oleate and palmitate of iron, and the copper is set free. When once the copper is set free in the metallic state, there is formed, as it were, a multitude of galvanic batteries which result in the destruction or oxydation of the iron. As to the butyric acid: In some fats there occur a compound butyrin—butyrate of glyceryl—corresponding to butyric acid, and from which butyric acid may be obtained in the same way that oleic acid is obtained from olein. This compound (butyrin) has been reported as found in olive oil, and the butyrate of copper or iron, which I found, may be due to this fact, or to the decomposition of oleic acid. It is not improbable that if I had time and a sufficient quantity of the material, it would be possible to show the presence of the deposit in your drums of the compounds of various other acids." Professor Leeds, Professor of Chemistry at Steven Institute of Technology, Hoboken, N. J., very kindly examined some of the same deposit, and verified the statement of Professor Nichols so far as to show the presence of a very minute quantity of copper in connection with the acids produced by the decomposition of the olive oil and tallow. Tallow was used at times, with olive oil, during the first year of the cruise, for internal lubrication of the cylinders and valves. During the following eighteen months, olive oil was the one lubricant used. After new bottoms were put in the drums and wrought iron connecting pipes substituted for the copper ones, plates of zinc were suspended in each drum to arrest chemical action. Their use was discontinued after one trial, owing to the trouble arising from the obstruction of the drain pipes by the oxide and other compounds of zinc which were formed,

and the method of cleaning and thoroughly draining each drum once a month for eighteen months was resorted to with most excellent results.

The approximate time it took the zinc suspended in steam of high or low pressure to oxidize, so as to leave no apparent element of metallic nature, was carefully noted by the officer of the watch in the steam log-book as follows: Nine days at sixty pounds pressure plus twenty-five days at an average pressure of twenty-five pounds in four drums; while in the sixth drum it was nearly sixty days decomposing under a pressure of twenty-five pounds. In the latter case, there was no connection with the cylinders.

In the pursuance of further enquiries into the alleged causes of the deterioration of iron in boilers, I was permitted, by the kindness of Professor Nichols, to examine the recent reports of the Boiler Committee, appointed by the British Government. In the thorough and careful experiments conducted by them at Sheerness, to determine the corrosibility of various irons and steels when under conditions similar to those in which marine and land boilers are worked, it was found that the per centage in favor of mineral oil was 46; this result was obtained by filling tubes with liquids and lubricants, containing, respectively, tallow and mineral oil, in which were placed discs of iron. The rods and discs in the tubes containing tallow and vegetable oil, were found to be coated with a black substance which was very tenacious in the water, and harder in the lower portion of the steam space, while the mineral oil retained its fluidity, and only required to be wiped off with a cloth.

The committee mention the experiments by Professor A. W. Hoffman of the College of Chemistry, England, in the interest of Messrs. Humphreys & Tennant, on the destructive agency of fatty acids, as follows: "Rods of different varieties of iron were placed in iron tubes with hermetically closed caps, the tubes being previously charged with water and stearic acid; the latter having been separated from tallow by the ordinary process of lime saponification. On opening them after being exposed for three weeks to a temperature of from 264° to 285°, corresponding to a pressure of from $2\frac{1}{2}$ to $3\frac{1}{2}$ atmospheres, the inner surface of the tubes, as well as the iron rods, were found to have been corroded in a great degree. A large proportion of oxide of iron was found in conjunction, and apparently in combination with the fatty acid floating in the liquid."

He also states in support of his theory as opposed to that of galvanic action, induced by iron and copper together being brought into contact with water and fatty acids, an experiment in Percy's metallurgy:

"For this purpose clean iron rods were surrounded perfectly by metallic copper coils, in such a manner that the two metals were nearly everywhere in perfect metallic contact; they were then introduced together with fatty acids and water into glass tubes, and exposed to a temperature of about 264° Fah. In some of these experiments distilled water was used, and in others salt water; after the lapse of eight days the tubes were opened, when on each of them a minute quantity of hydrogen was found. The iron, where not covered with the copper wire, had become coated with a dark brown deposit, perfectly similar to that which appears on iron when treated with water and fatty acids alone; the copper had remained metallic, and when the coil was removed, the iron where it had been covered by it, remained perfectly metallic, and no corrosion could be detected." Professor Hoffman states that the foregoing experiments strongly confirm him in the opinion "that the corrosion of iron in boilers worked with surface condensation is due to the direct action of free fatty acid." In furtherance of the support of the above opinion, he mentions the examination of several deposits from boilers of vessels worked with surface condensation as follows: "In but one of the samples of deposit was found any trace of copper. In the absence of accurate information upon the particular circumstances under which cupriferous deposits were found, it would be useless to speculate upon the origin, but the occasional occurrence of small quantities of copper in this description of boiler deposits, cannot, I conceive, justify the hypothesis that it is an essential condition of the corrosion so con-

stantly occurring where copper is entirely absent."

To resume the report of the committee: "They find that during the time the grease remains in contact with the copper or brass surfaces of the condenser tubes, there may be formed a grease compound containing copper in an oxidized state. The compound may be either oleate or stearate or other organic salt of copper, and is the result of the joint action of a fat acid and air upon the copper in the tubes. Such a compound is only produced when either tallow or vegetable oils, or any like substances capable of saponification, are used as lubricants; the so called mineral oils being incapable of contributing to its formation. To illustrate this difference, coils of sheet brass were placed in common tallow, and other similar coils in mineral oil, and heated day by day for four months, air having free access to the surfaces. The sheet brass in the tallow weighed 1029.30 grains, and lost 14.10 grains, and the tallow was colored green, while that which was placed in the mineral oil (weight, 1101.40 grs.) lost only .20 grains, and the oil grew darker. It is believed that the amount of corrosion supposed to have been contributed by copper or its compounds has been greatly over-estimated, and the evidence of witnesses upon this point was extremely indefinite, especially as to the forms in which the copper reached the boiler. That it does so, there can be no doubt, because the feed pipes are sometimes considerably acted upon, chiefly at the bends or elbows, and the tallow or saponifiable oil has been carried by the steam from the cylinders to the condensers, and accumulates upon the surfaces of the tubes, the greater portion of which may be transferred to the boilers with the condensed water."

In 1873, while Dr. Jerome H. Kidder, of the U. S. N., was on duty at the Naval Laboratory, New York, a specimen of the substance that came from the condenser at Hecker's Flour Mills was ex amined by him, which, in the course of experiments, seemed to have established the presence of oleate of copper as the probable cause of the destruction of boiler tubes. The result of his experiments were communicated to VAN NOSTRAND'S ECLECTIC ENGINEERING MAGAZINE in February, 1874, the substance being as follows: The presence of oleate of copper is accounted for in the decomposition of the olive oil, along the line of friction between the piston and sides of the cylinder, into oleic acid and glycerine. A small portion of the oil then having become decomposed into oleic acid and glycerine, and the latter passing through the condenser first harmlessly, and the former somewhat later. He supposes the oleate of copper to be then formed in the condenser, which appears as bright green greasy masses, which are carried from the condenser into the boilers, and being quite insoluble in water, the masses accumulate (in accordance with a familiar law) in those parts (at the ends of the tubes) that the most corrosion is found, settling upon one of the iron tubes a mass of oleate of copper adheres thereto, and, favored by the conditions of high temperature and pressure, the deposition of copper and absorption of iron begins. If the oleate of copper were soluble in the water of the boiler, the erosion of the tubes would be uniform over their entire surface. Being insoluble, however, its action is confined to the surface of contact, hence the small holes characteristic of this kind of injury. Since, as shown by experiment, copper thus deposited will remain adherent only to perfectly smooth iron, and since boiler tubes are never in this condition, the copper is probably removed by the action of water as fast as deposited, leaving constantly a fresh iron surface for further action. Whether the action, which takes place in the boiler, be galvanic or chemical, is uncertain, if indeed, there be any essential difference between these two modes of action, other than a difference of degree. Whether the percentage of sulphuric acid that is sometimes used in the manufacture of merchantable tallow (and not thoroughly cleaned of the same) has an injurious effect upon iron, is a question that seems to have had little consideration. Professor Dassaunce, of the French Academy of Science, states in his general treatise on the manufacture of soap, that in the manufacture of tallow and lard oil, a quantity of concentrated sulphuric acid is used to expedite the process of extracting all the tallow from the dregs. The follow-

ing are the proportions given: 1,000 pounds of tallow, 25 gallons of water, 10 pounds of concentrated sulphuric acid. Mention is made of the same mode of treatment in M. V. Regnault's elements of chemistry. The fats, after being heated by steam, in boilers, are first treated with a quantity of concentrated sulphuric acid, which varies from 6 to 15 per cent., according to the nature of the fat.

The committee to determine the destructive action of air upon iron, placed iron discs in two groups of tubes, the circumstances being identical as regards the water and lubricants. In one case the air was excluded, and in the other admitted weekly, with a result of 19.7 per cent. in favor of the exclusion of air. It was also found that perfectly dry air has no action upon compact iron at the ordinary temperature; neither has water when perfectly free from air, and from a series of experiments to illustrate the action of oxygen upon iron immersed in water under different conditions, it appears that pure distilled water, perfectly free from solid matter, allows of more corrosion than sea water, and that the oxydation which has been ascribed by many of the witnesses, and others, to the action of pure water, in itself considered, should be attributed to the oxygen contained in the air dissolved by such water, the water acting as a means of transfer for the oxygen to the iron. A good illustration of the destructive action of oxygen upon iron is by Rand C. Stieman, in No. 124 of the *Scientific American* supplement, in which he gives description of his invention to yield a product which shall be equal in quality and price to "English Red," and to the native ochre obtained by mining in France. The process consists in the alternate action of fresh water and atmospheric oxygen upon wrought iron turn ings. So destructive is the action, that in 24 hours it was found to yield about 1.5 per cent. of hydrated oxygen. A ton of borings thus treated for one week would yield 2 cwt. of the product.

Concerning the use of zinc as a preventative of corrosion, the committee found the evidence to be both conflicting and defective. "The results obtained from some experiments by them, show, that when properly applied it does protect iron and steel under the ordinary conditions of working, from a large proportion of the corrosion to which they would have been subjected had the zinc not been present. Apart from any consideration as to the existence of galvanic action in boilers, the protective value of zinc may be stated as follows: If a boiler is worked in the ordinary manner with sea water, its exposed surfaces will be vulnerable to the action of all the influences which may be present capable of affecting iron. But if zinc be introduced and applied in the manner which has already been pointed out, *i. e.*, perfect metallic continuity insured between it and the iron, galvanic action is set up between the two metals, and the latter is compelled by the presence of the former—it being of a more electro-positive nature—to assume a negative condition towards corrosion or oxydation. Such being the case, the metallic condition of the iron is preserved at the expense of the zinc, which loses in course of time its metallic nature by oxydation, in which latter condition it ceases to afford protection, and must, therefore, be renewed at intervals. In cases where this metallic continuity has not been effected, the zinc would share with the iron surfaces of the boiler any corrosive action that might be present, in proportion to the surfaces exposed, which in any case would be relatively small; there would be no electro-chemical relation between metals, and the different results observed by marine engineers may have depended upon the fortuitous circumstances that, in some cases, metallic continuity had been unintentionally effected in suspending the zinc from the stays of the boiler.

"This seems to be a very probable explanation of the discordance of the opinions held by many as to the protective value of zinc. A uniform and more reliable method of applying it is desirable, as in the present practice of suspending zinc from the stays, there may or may not be metallic continuity between it and the surfaces to be protected."

Engineer-in-Chief, William H. Shock, of the U. S. Navy, recently issued instructions to the engineer officers of naval vessels to make careful experiments with zinc to determine its practical

value in preventing or arresting the interior corrosion of marine boilers. It is in place to call attention here to a fact mentioned in a report by Colonel Kurtz and Captain Brown of the U. S. Army Engineer Corps, to the Engineer-in-Chief of the Army upon the durability of zinc, and the effect of sea water and exposure upon iron pile shafts of the Brandywine shoal light-house, in which they state that of the zinc collars on the shafts, placed there twenty-five years ago, ten are visible above low water mark on as many piles. There seems to be very little doubt but much of the irregular corrosion of wrought iron is due to want of homogeneity; this, Professor Hofman explains by taking a plate of wrought iron presenting a clean and apparently uniform surface, and covering the surface everywhere with an equal depth of acid, when it will generally be found to yield very unequally in different parts to the action of the solvents by becoming furrowed, and, in some parts, pitted with deep excavations, which ultimately become peforated often as circular as if drilled with a tool. Again, the mere action of the atmosphere reveals unequal texture of the metal, as a high polished plate of iron, when allowed to rust in the air, is observed to be very irregularly attacked. Some parts of its surface retain their first lustre long after other parts have become thickly coated with oxide. Any one acquainted with the ordinary manufacture of wrought iron cannot be surprised at the result, it being an aggregate of fibres mechanically heated and welded together, but not blended into homogeneity by *fusion.* The red-hot ball in the puddling furnace is but a sponge filled with a semi-fluid silicious slag, which is squeezed out, more or less perfectly by mechanical pressure. The presence of the merest traces of these impurities between the adjacent fibres of the iron may prevent their welding, and leave an opening for chemical agency to penetrate. The passage of the iron through the rolls may mask, but cannot obliterate, such exposed points, which, though imperceptible to the naked eye, may, under chemical attack, become the pits and perforations we are seeking.

Of the methods proposed for the preservation of iron and steel are those known as the hot steam process and hot air processes. To Professor Barff, of Kensington, England, according to the English *Engineer*, is due the credit of first reducing the work of protecting iron by the hot steam process. The former method consists in exposing the metallic surfaces, while heated to redness, to the action of superheated steam, thus producing upon their surface the magnetic oxide of iron, which, unlike common rust, possesses the characteristic of permanency, and adheres closely to the metallic surface below. The magnetic oxide is practically insoluble in sea water and other weak solutions.

The hot air method is accredited to Mr. G. Bower of St. Neats, England, and though the results produced are substantially the same, the methods of manipulation employed are very different. The use of steam is dispensed with, and he relies on the air for his supply of oxygen in forming the coating of magnetic oxide. As to the relative value of the two systems, and their advantages and disadvantages as applied to manufacturing purposes on such large and important work as boiler making and armor plating, by the possible interference with the coating on the rivet heads and seams that require to be caulked, and the working of iron, is a matter that can only be concluded by careful experiment.

As early as 1869, Colonel Paine, of the Engineer corps of the army, produced, by a process of his own, a surface of magnetic oxide upon steel measuring tapes, which has proved a perfect protection from further rusting, and the tapes are yet in good condition.—(VAN NOSTRAND'S MAGAZINE, June, 1878).

One of the many causes of the deterioration of marine boilers is due to the sudden changes of temperature, produced by pumping in cold water in place of that blown out to keep the density in the boiler within certain low limits, thereby causing leaks from unequal expansion and contraction. As to limit of density of water in a boiler is a question upon which engineers seem to be at variance. It appears, however, from the experiments of M. Cousti, that the sulphate of lime, which is contained in sea water in a large proportion at a temperature of 60°, is precipitated upon an in-

crease of temperature, so that at 212° merely traces are left. In consideration of the foregoing, it would seem that limiting the density of the water in the boilers to $\frac{3}{32}$, less sulphate of lime would be deposited, the life of the boiler prolonged, and better economical results obtained.

The evidence taken by the committee show that in many steamers the density of the water in the boilers is carried even beyond $\frac{3}{32}$, and in concluding their report on this subject, state the density should in no case exceed three times, nor be less than one and a half times that of sea water. As so much difference of opinion does exist as to the proper density at which to carry the water in marine boilers, it is to be hoped that a series of experiments will be instituted in this country to determine the merits of so important a question.

As to the cause of the rapid determination of the steam drums of the U. S. S. Swatara, there can scarcely be any misconception, but that it was due to the action of fatty acids found in the deposit, and to the galvanic action, if any, induced by the presence of copper, free and in combination.

The presence of copper in combination with fatty acids undoubtedly occurred from the action of the acids upon the copper pipes, while the engines were at rest. (Surgeon J. H. Kidder, of the U. S. Navy, suggested in an article published in Van Nostrand's Engineering Magazine in 1873, that oleic acid might have been set free by the high temperature of friction between the piston and cylinders, whereby the film of oil used for lubricating was decomposed into oleic acid and glycerine, attacking the copper exhaust pipes and condenser tubes on its passage to the boilers). That mentioned by Professor Nichols as "minute particles" was from the bends of the pipes, at which point the planished surfaces were wholly destroyed while undergoing the severe strain of bending.

Too much care cannot be taken to keep the boilers and steam drums, when not in use, free of water, as the alternate wetting of the parts cannot but work great injury. This Mr. Steiman proves so clearly in his experiment on the alternate action of atmospheric oxygen and fresh water upon wrought iron turnings.

Every cruising ship in the U. S. Navy, is, where space will permit, fitted with an auxilliary boiler of the low pressure type, and used exclusively for heating ship and distilling water. The design is such as to render it readily accessible in all its parts for cleaning and repairs, thus lengthening the life of the main boilers by being kept free from any injurious deposits from sea water, and the unequal expansion and contraction occasioned by the use of one of several furnaces of a large marine boiler, which is oftentimes the case, for the purpose of distilling or heating ship.

In concluding this paper, attention is called to the fact that the longevity of so important a portion of the power as the boilers of a war ship, depends, not only upon being managed by a full complement of efficient and able engineer officers, but, in a great measure, upon their construction and accessibility for cleaning and repairs. So far as material and workmanship are concerned they may be faultless, and yet, certain important points overlooked, which greatly impair their circulation and evaporative efficiency.

ON THE CONSTANTS OF THE CUP ANEMOMETER.

By Rev. T. R. ROBINSON, D. D., F. R. S., &c.

From Papers of the Royal Society.

In a previous paper the author detailed experiments made by attaching anemometers to a whirling machine, and the conclusions to which they led. He was, however, doubtful of the accuracy of the method, and proposed one depending on the action of natural wind. He has tried this, and he thinks successfully. Two instruments of the Kew type, differing only in friction, were established 22 feet asunder on the roof of the house and 16 feet above it; the number of turns made by each, and the time, were recorded by a chronograph, and from these, v and v',

the velocity in miles per hour of the centers of the cups was known.

The friction of one of these (K) was constant; that of the other (E) was varied by applying to a disk on its axle Prony's brake, which was connected with a spring balance whose tension was recorded during the time of experiment by a pencil moved by clockwork. Thus the mean friction was obtained. It ranged from 353 grains to 4,982.

The equation of an anemometers motion is

$$V^2+v^2-2Vvx-\frac{f}{a}=0$$

where V is the unknown velocity of the wind, a and x two constants which are to be determined. Each observation gives two equations in which there are four unknown quantities, for it is found that the value of V changes from one instrument to another. This is partly owing to eddies caused by the buildings, but also in great measure to irregularity of the wind itself. It is, however, also found that these wind-differences are as likely to have + as − signs, and, therefore, it may be expected that their sum will vanish in a large number of observations. The ordinary methods of elimination fail here even to determine with precision a single constant, and he has proceeded by approximation.

Assuming the value of a given by the actual measurements in his paper = 15.315 at 30″ and 32° for 9-inch cups, and that there is no resistance as v^2 except that in the equation, and assuming an approximate value for x, we can compute V and V′. The difference between these must be due to an error in x and to w the wind error, and taking the sum of a series we have

$$S(V'-V)+Sw=\Delta x\times S(e-e');$$

$$e \text{ being} -\frac{V}{\sqrt{x^2-1+\frac{f}{av'^2}}}.$$

If the observations are sufficiently numerous $Sw=0$, with the assumed $x+\Delta x$ thus found, recompute the V till the sum of $V'-V$ is insensible, and the final x will give V with a high degree of probability. Twenty-one observations gave a value of x considerably larger than what was obtained with the whirling machine, and of course the limiting factor (that when v' is so large that $\frac{f''}{av'}$ may be neglected). It is for the Kew type 9″ cups 24″ arms=2,831. In this series the differences are so evidently casual as to show that neither a or x change with v.

With this x, K gives the true value of V at it; therefore, if any other type be substituted for E′ it is easy to find its x, for its a is as area of cups, its f'' is known, and assuming its x' and computing as before, we get similarly its Δx. He tried five different types and obtained very unexpected results, for he found that the x varied as some inverse function of the diameter of the cups and of the arms. He gives its values :

No. 1.	Original instrument....	12″	cups	23.17	arms,	x=1.5880,	limit	2.812
" 2.	Kew	9	"	24,	"	1.5919,	"	2.831
" 3.	"	9	"	12,	"	1.7463,	"	3.035
" 4.	"	9	"	8,	"	2.1488,	"	4.051
" 5.	"	4	"	26.75	"	1.8587,	"	3.425
" 6.	"	4	"	10.67	"	2.5798,	"	4.958

No. 6 is similar to No. 2, and it might be expected that their constants would be equal. The cause of these differences is partly the eddies caused by the cups being more powerful when the arms are short, but still more the presence of high powers of the arm and diameter occurring in the expressions of the mean pressures on the concave and convex surfaces of the hemispheres. In the present state of hydrodynamics we cannot assign these expressions, but we know enough to see that such powers may be present.

As each type of anemometor has its own constants, the author would suggest to meteorologists the propriety of confining themselves to one or two forms. For fixed instruments he considers the Kew one as good as any, and would wish to see it generally adopted. For portable ones he has no experience except with Casella's 3″ cups 6″ arms, which he found very convenient; he has not, however, determined its constants. Some selection of the sort seems necessary if it is wished to have an uniform system of wind-measures.

THE ARTS AND INDUSTRIES OF CHINA.

By JAMES A. WHITNEY, LL. D.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

NOTHING affords more facile proof of the common origin of races now remote from each other, than does the identity of terms applied to the necessaries of life, and the similarity of the rude implements by which the simple operations of industry are performed. The former has shown the primal unity of Sanscrit and Zend, and traced to its furthest source the origin of the Aryan peoples. The latter shows that the arts of craftsmen had reached a certain excellence before the European parted company with the natives of India. But by neither of these clues can any connection be traced between China and other lands. The language, even in its simplest roots, has no analogue; and the implements of industry have characteristic forms that demonstrate their orgin to be distinct. The anvil of the Chinese smith is not flat like the anvils of other countries, but convex on its face or working surface; and the bellows of a Chinese forge, instead of moving vertically, has a horizontal stroke. The paper of the Chinese is thin and weak; is printed on one side only, but doubled to present a folded edge at the rim of the the leaf, and a printed surface on either side. The chain pump of China has a square barrel, that of other lands is cylindric. Brass is made elsewhere by melting together copper and zinc in a crucible, in China, by suspending thin sheets of copper, heated almost to melting, in the vapor of molten zinc. The German silver of Europe is made by combining the materials in their metallic condition, its Chinese equivalent by mingling the ores of the metals and reducing them together to produce the alloy. Spangles are made, not by cutting or stamping from sheet metal, but by flattening wire first bent into annular form. Pewter vessels are not cast, but are shaped by hammering upon a block. The primitive mill used in many countries —in Normandy, for crushing apples for cider, in South America, for pulverizing ores, in our own country, for powdering the scoria of assaying pots—and composed of a wheel traveling in a groove or channel, has, among western nations, its wheel running continuously in a circular track around a vertical axis; in China, its wheel working to and fro in a semi-circular track, and around a horizontal center of movement. Chinese lanterns are not made of horn, like those of the Romans, or of perforated metal, as long since in our own country, or of glass, as is now universal, but are of varnished paper stretched on bamboo frames, sometimes of little cost for the multitude, sometimes of great intrinsic worth, and blazoned with titles, for the mandarins. The domestic industry of other lands has obtained the healthful acid of vinegar from the acetic fermentation of the sweet juices of fruits; the Chinese, by placing in water the sea polypus found along the coasts. Fish culture, now a matter of government solicitude in our own and other countries, is old in China, but the Chinese fish culturist puts the spawn in an eggshell and places it under a setting fowl, and after due delay breaks the shell into water warmed by the sun. These are not trifles. They show that in the earliest period of her existence China drew nothing from other lands. In what she required she originated all, she imitated nothing.

And even in the things that for ages have been common in other countries, we find that in unnumbered instances their paralellism with those of China is of but modern date; that they, too, at former periods have shown by their use in China, and nowhere else, that they were but further proofs of the self-sufficing and self-supplying character of the Chinese mind. It was this that dis covered the polarity of the magnetic needle and applied it to use in the compass, and obviated its dip by the simple device of placing its weight below the point of suspension, and it was this, too, that first perceived, and made allowance for, the variation of the needle from

the true pole. It was to this that was due the invention of printing and its perfection to the highest degree permitted by the language, for with the Chinese alphabet there is no advantage in interchangeable types. It was from this, too, that arose the invention of paper in the first century of our era, and the production of inks having a carbon base as with the printers' ink of to-day, and by the same token the first to manufacture lampblack from the burning of oils. It was this that devised the drilling of grain as distinguished from broadcast sowing, a method that saves in the annual seed time of China as much as would feed the inhabitants of Great Britain and Ireland. The primitive Chinese mill for the hulling of rice is substantially the same as the modern mill for decorticating wheat, and another apparatus for the same purpose, a lever armed with a stone at its outer end and actuated at the other by arms radiating from the shaft of a water-wheel, differs in no essential respect from the principle of the trip hammer. What in our day is known as the Belgian System of Canal Propulsion, and now on trial on the Erie Canal, was derived from the Chinese method of crossing rivers. The plan by which life-boats are worked to and fro for the relief of stranded vessels is the same as that by which the ships of Mandarins were drawn against the current of the Yellow River centuries ago. The paddle-wheel was used for purposes of propulsion in China long ages before it revolved in western waters. It was the structure of the Chinese junk that afforded the prototype of the watertight bulkheads used in our modern steamships. Upon rafts or hurdles of bamboo the Chinese spread layers of earth, which they cultivated like garden soil, and thus anticipated by ages the floating gardens of Mexico. In our own country, a factory system of making cheese and butter was initiated about thirty years ago; the like was done by Chinese makers of sugar long centuries before the existence of our continent was known to the eastern world; and the same workers of the cane first used the waste bagasse for heating the evaporating pans. Within the past sixty years, the division of labor has become the distinguishing feature of the industrial systems of Europe and America; the potteries of Kingtze-Chin have practiced the same for many ages, the consecutive labor of fifty different workmen being necessary to the production of a piece of the finest ware. The Chinese terraced the slopes of the mountains with walls of stone for the growth of vegetables, as the shores of Lake Leman are terraced to-day for the cultivation of the vine. Mindful of the chemistry of the soil, they early learned to temper sandy lands with clay, and clay lands with sand; and they carefully gathered and applied all manner of fertilizers, at a time when the wealth of Roman plains was passing through the great Cloacae to the Tiber and the sea. They they were the first to unwind the cocoon of the silkworm, and weave fabrics from its threads. They were the originators of porcelain, and their name, Kao-lin, for the clay of which it is made, has passed into the industrial nomenclature of Europe. They invented gunpowder, not only for fireworks, and for explosive mines in war, but for firearms, for the embrasures of the great wall are fitted for the reception of the swivels of wall pieces, and more than six centuries before the Christian era their cannon bore the inscription, "I hurl death to the traitor and extermination to the rebel." And they discovered, too, in remote times, that the best charcoal is made from willow, a fact recognized by manufacturers of gunpowder in all parts of the world to this day. They burned petroleum in lamps long before such use was dreamed of among Western peoples. They sunk salt wells hundreds of feet through varying strata, and finding that inflammable vapors arose in vast volumes, they led them to the furnaces for use as fuel in heating the factories. They rendered potable the muddy waters of their rivers by treatment with alum, a process employed in Europe with effect for removing clay and other earths from water intended for use in various branches of manufacture. They adopted the decimal system for measures of quantity and weight and value, centuries before French legislators recognized its utility, or French scientists formulated its application to the traffic of Europe; and now, as in the days of the first coinage of copper, the *lee* or *cash*, a disk with a square hole in the center to

permit it to be placed on a string, is the tenth of a *fen*, and the *fen* is the tenth of a *chen*, and a *chen* is the tenth of the value of an ounce of silver.

Their units of volume and length were literally native to the soil, for the one is the cubic contents of a hundred of the grains of the Kow-leang or high millet, the *Holcus Sorghum* of the botanists, and the latter the linear space occupied by a certain number of the same grains, which also afforded a standard of weight. In minor industries they saved the culm and dust of coal, and mingled it with clay and soft earth from the marshes, to form an artifical fuel, an invention currently believed in other countries to be of recent years. They were the first to make spectacle glasses from sections cut from rock crystal. They made cloth from the bark of the nettle—a project revived in Germany, as new, within the past five years—and applied to the extraction of color from a native plant the processes by which indigo is extracted from the Indigofera. They hatched the eggs of fowls by artificial heat, the method by which ostriches are incubated on the ostrich plantations of South Africa. They found food in the roots and the seeds of the lily growing in reedy ponds, and purified the nauseous oil of the palmi christi until it became edible and sweet. They trained the sheep to carry burdens through the highest defiles of neighboring mountains, and taught the brown cormorant to fish in behalf of his owner in the dun canals.

Such were the manifestations of the Chinese intellect as applied to the useful arts. Such were the implements and methods by which the genius of China manifested itself in originating the industries by which her constantly increasing population has been sustained, and which, through almost unnumbered ages, have formed the basis of her power and the foundation of her home and foreign policy. But is to be remarked, and the fact illustrates not only the nature of her people, but the policy of the government, that every art, every implement or method, related only to the furtherance of manual operations. Nowhere is there the slightest evidence of intent to encourage labor saving machinery, which, by dispensing with the labor of some, lessens the cost of the products of labor to all; but everywhere, the ready devising and adoption of whatever furnished employment for human hands, or opened new sources from which the individual could derive food and raiment by personal labor. Within these limits all was devised that was required for use in the agriculture or manufactures of the country. But the limit was early reached, Hence the lack, through many ages past, of industrial advancement, which has given to the arts of China the almost stereotyped character manifest in her social and political institutions. Arts and industries, thus restricted, could only attain excellence through the highest development of mechanical skill, and their rewards could only be obtained through the cultivation of certain faculties, and these not separately, but together, which may be briefly enumerated as accuracy of perception, closeness of calculation, imitativeness in a rare degree, and unwearying patience. The conditions of existence, from the time of the building of the first mud cabins on the banks of the great rivers, has developed these qualities with an intensity not equaled elsewhere in the world. And thus, a symmetry, perfect of its kind, in the nature of the people, has enabled them to excel to the utmost within the narrow boundaries assigned by policy, by usage and tradition. And this excellence, and others of kin to it, which constitute an indefeasible merit, so far as concerns the Chinese in their own country, is a standing menace as an element in the relations of China with the rest of the world.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The last issue of Transactions contains the following papers:

No. 199. Ship Canal Locks to be Operated by Steam, by Ashbel Welch.

" 200. Discussion on the Use of Steel for Bridges, by William Sellers.

" 201. Remarks on the Causes of Fall of the Arched Approach to the South Street Bridge, Philadelphia, by J. G. Barnard.

" 202. Note on Kutter's Diagram, by Chas. H. Swan.

IRON AND STEEL NOTES.

Welding Iron and Steel.—German engineers are now discussing eagerly a question which has seriously engaged attention in this country, and though nothing conclusive has been reached abroad, it will be profitable to review briefly the conflicting opinions offered, based upon experience, and in some case upon experiments of a specific character. The last German engineer to take up the subject is Herr C. Petersen, of Eschweiler, from whose paper, read before an association of railroad engineers, we glean the following : "The welding of iron is dependent upon its property to assume a pasty state within a certain range of temperature, and it may be stated, in a general way, that the facility with which the welding may be performed is dependent upon the duration of this peculiar condition. Leaving out of consideration other circumstances affecting welding, it is conceded by the majority of metallurgists that an increase in the percentage of carbon in tne iron impairs the property of welding, and it is generally believed that when two per cent. is reached it ceases entirely. It might be concluded that, therefore, it is desirable to keep the carbon within the lowest limits attainable, but there is some diversity of opinion on this point, because a second important condition for good welding comes into play. It is necessary, in order to unite two pieces of iron, to make the surfaces to be welded free from any coating of oxide, a matter which is generally reached by fluxing the oxide by means of sand, borax, &c. ; and some hold that a certain percentage of carbon is necessary in order to afford material for the reduction of this oxide. Wedding, among others, maintains that such is not the case, and that the silicate of iron contained in wrought iron plays an important *rôle.* These theoretical considerations have quite recently become of considerable interest, because they may offer a clue to detecting the reason why the steel produced by the open-hearth and Bessemer processess is generally inferior as regards welding power to wrought iron, an inferiority which stands in the way of the more general adoption of steel in place of wrought iron. The former, it is true, can be welded, but there are many practical difficulties. Certainly steel-headed rails show a case of good welding, and tires, tubes, &c., have been made of Bessemer steel on a large scale, but still steel cannot compare in this respect with wrought iron. It is said that hot working in the Bessemer converter or open-hearth steel furnace favorably affects the welding power, and this is explained by pointing to the fact that hot steel will contain a smaller amount of oxides mechanically mixed than that produced at lower temperatures. Herr Petersen claims that silicon is injurious, while Herr Koehler, of Bonn, during the discussion following the reading of the paper, held that it was not alone not injurious, but actually favorable for good welding. Herr Helmuth took a different view, and stated that at Bochum, during a series of experiments in an open-hearth furnace, they tried keeping the silicon low, but reached no results, and were similarly unsuccessful by increasing the percentage of phosphorous. They then turned to the Bessemer process and commenced over-blowing, which improved the welding, though not in a sufficient degree. By using oxides of iron, however, they obtained much better results, but they did not follow out the matter, because they found that pieces welded together had a yellow red fracture near the weld, and Herr Gresser, of Grafenburg, added that the same tendency to red-shortness was observed by them when making a weldable material in the open-hearth furnace. In using the Terrenoire alloy they found that a good product was obtained by adding about four times as much manganese as silicon. It was, however, abandoned on account of its high price. Herr Petersen concludes by giving some interesting data in regard to the influence of arsenic upon the welding of iron. A lot of inch rod was rejected on account of difficulty in welding, and it was found that the heated rods had a fatty lustre, and that two rods laid one upon another slid off as though the surfaces were polished. This took place, although the balls in the puddling furnaces and the piles welded well. The cause of this anomaly was found to be that the injurious effect of the arsenic comes out strongly only after the carbon has been considerably reduced. The following analyses are given as representing the composition of the pig used in making these rods, the first being white, the second gray pig:

Sulphur	0.774	1.843
Phosphorus.....	trace	trace
Copper	0.090	0.580
Arsenic.........	4.250	5.980
Antimony	1.145	1.068

Steel in China.—The steel manufacture has assumed a considerable importance in China, especially along the upper Yangtze, from which district the metal is shipped to Tien-Tsin, The price obtained for the steel in China is higher than is secured by that imported from Sweden. Chinese metallurgists recognize three different qualities of steel. The first of these is produced by mixing crude iron with wrought iron and submitting the mass to the action of fire ; the second, by the repeated heating of pure iron ; while the third consists of the native steel, which is produced in the south-western districts. The different names by which these various kinds of steel are known are the following : The "twan-kang," or ball steel, on account of its globular form ; the "wan kang," or tempered steel ; and the "wee tei," or false steel. The Chinese seem to have been acquainted with the manufacture and use of steel from the earliest times ; and at the epoch of the Han dynasty, iron masters were appointed in the different districts of the ancient Leangchow, whose duty it was to superintend the iron manufacture.

Deflection of Iron and Steel Rails.—In the *Comptes Rendus* of the Paris Society of Civil Engineers is a paper by M. Tresca, giving the results of some experiments on the deflection of iron and steel rails between the limits of elasticity and rupture. They show

that, for these two metals of ordinary commercial character, the co-efficient of elasticity is nearly the same, thus confirming certain special experiments in 1857 and 1859 upon Swedish iron and cementation steel made from such iron. M. Tresca finds that the limit of elasticity for a given bar may be extended in proportion to the strain to which it had been previously submitted, and that the elastic limit may be pushed almost to the point of rupture without the co-efficient of elasticity having varied in any perceptible degree. The metal, when it comes from the work-shops, is in a state of instability, which disappears only by use; it becomes, by means of the actions to which it is successively submitted in its employment, more homogeneous and more elastic, but at the same time a little more flexible.

RUSSIAN TOOL STEEL.—The tool steel used in Russia is imported chiefly from England, although some private firms are using German steel. The Obouchoff Steel Works, near St. Petersburg, are, however, making tool steel for their own use, and are also filling some orders for other Russian works. At the Obouchoff Works, Whitworth's system of compressing fluid steel has been for some time employed, and it is now being turned to account for the production of solid ingots of tool steel. The steel is prepared in crucibles from a mixture of blister steel with refined cast iron and ferro-manganese, the materials employed being very pure. The Oural blister steel used contains carbon 1 per cent., silicon 0.06 per cent., manganese 0.22 per cent., and phosphorus 0.07 per cent. The application of the Whitworth system of compression enables perfectly sound ingots to be obtained, the whole of each ingot being available for the production of tool steel by the further processes of hammering and rolling.

RAILWAY NOTES.

STARTING upon the basis that there are more than 10,0000,000 car-wheels in use on the railways of the United States, that the average life of a wheel is eight years, and that it requires a little over a ton of pig iron to make four wheels, an American contemporary concludes that there are required 1,250,000 new wheels to replace those worn out each year, and to make these over 312,500 tons of pig iron are required. As 1,250,000 wheels are worn out each year, and as the average weight of a worn-out wheel is about 515 lbs., something like 287,389 tons of this old material are available for re-manufacture, The difference between this sum and 312,500—the approximate weight of the new wheels—shows the weight of new material consumed per year in the manufacture of car-wheels, assuming that all the old wheels are manufactured into new ones. Manufacturers guarantee wheels to run from 50,000 to 60,000 miles, but they not unfrequently greatly exceed this.

ON a down grade of 1 in 38 on the Aaachen Railroad, in Germany, the amount of rail wear per 1,000,000 kilo-metric tons (of 2,205 lbs.) gross weight was 3.059 in., so that a rail was completely worn out in five years. On August 10, 1878, as an experiment, cast steel blocks were substituted for the wrought iron ones on the left side. On taking measurements, May 6, 1879, it was found that the left rail was worn down 0.287 in., the right rail 0.35 in., while formerly the rail on the right side was least worn. For the sake of obtaining a certain result, the brake blocks were exchanged right with left, on the 6th of June, and the height of the rail (twenty lengths on each side of the track) carefully measured. According to the measurements made on September 18 and November 24, 1879, the wear on the steel brake-block side amounted to 0 5 in., on the side where the wrought iron blocks were used, 0.086 in. per million tons gross load. On a down grade of 1 in 75, between Heissen and Mülheim, the rail wear, with a gross load of 34 million tons, amounted to 0.507 in. in eight years. The chief engineer of the road can only attribute the enormous amount of wear to the fact that the soft wrought iron blocks hold the wheels perfectly tight, while the hard steel has not such a grip on them, they occasionally slip round, and less friction results to the track.

SPEAKING of the railway across Newfoundland to which the Colonial Legislature has committed itself, the *Colonies and India* says: Starting at St. John's the line will take a south-westerly course for 30 miles, and, gradually bending to the north-west and west, will pass along the narrow neck of land which separates Trinity Bay from Placentia Bay. Hence it passes in a general westerly course to St. George's Bay on the west coast. The country to be opened up by this railway is well watered and well wooded, resembling the general features of the Cumberland Lake District. The highest land traversed is 1,100 feet above the sea, and the total length of line will be about 350 miles, the distance in a direct line being 275 miles. Much of the country has hardly been visited by white men, and it is described as affording rich pasture land. The district of the western terminus, St. George's Bay, is one of the healthiest districts in the world, free from fogs and from the occasional severity of the weather felt in other parts of the island. It is hoped that eventually, communication, by means of ferry steamers, will take place between St. George's Bay and the mainland, thus enabling passengers and goods to be carried without change of train from St John's to any part of the Dominion of Canada, and saving about 1,000 miles of sea voyage.

ONE of the subjects reported upon at the technical convention of the German Railroad Union in 1878 was the lighting of cars. Reports were asked from the several companies with regard to the improvements effected in the illumination of passenger cars, particularly with gas, and the cost of applying, keeping in order, and running the different systems. Forty-five reports were rendered. Six corporations, representing 17.7 per cent. of the passenger coaches owned by the roads reporting, used gas, chiefly prepared on the Pintsch system; in one instance no other form of lights was used on the road, and all expressed satisfaction and an in-

tention to extend its use on account of the cleanliness, saving of labor, and superiority of lighting power. Five roads employed stearine candles in closed lamps, and 44.8 per cent. of the cars are lighted by oil lamps, the majority burning the commonest vegetable oil with Argand burners in the first and second class carriages, and common flat wicks in the lower classes. Some of them employed lamps with the oil reservoir above the flame to prevent the oil getting too thick to burn in cold weather; the supply of oil carried is sufficient for a ten hours' journey. On three roads American mineral oil was used in closed lamps with much better effect.

ENGINEERING STRUCTURES.

London Water Supply.—The following proposal to supply the metropolis with water from Bala Lake, in North Wales, has been submitted to the Secretary of State for the Home Department, by Mr. J. W. Welborne, for consideration by the Committee of the House of Commons now sitting:

"The water of Bala Lake has been carefully tested and proved to be equal in purity to the water of Loch Katrine, and ample in quantity for the supply of the metropolis. It is also probably sufficient for the towns *en route*. The country adjacent is sparsely populated, and a few mountain sheep and grouse constitute the occupants of the surrounding hills, hence there is a minimum of possible pollution. The rain fall registered at Bala for the year 1876, was 52.69 inches which is about the average rainfall there. The lake is nearly four miles long, by three-quarters of a mile wide, covering 1,100 acres. The water-shed of the district contains 35,392 acres, or 55 square miles, this, with the Bala register of rainfall would, after deducting 10 per cent. for absorption, give 37,040,000,000 gallons per year, or 104,000,000 per day. But inasmuch as Bala lies on a level with the lake, the register of the rainfall there does not represent the rainfall of the district. On the surrounding mountains the rainfall is probably twice as much as in the valley, which will leave a large surplus for supply, after giving compensation to the river.

"The lake is 553 feet above Trinity high mark, and 300 feet above Stanmore, where it is proposed to make the reservoirs. By embanking the lake 5 feet, and drawing down 2 feet below the present level, sufficient water can be impounded to supply 104,000,000 gallons daily, for thirty seven days without any rainfall. Should further supply be required 50,000,000 gallons per day can be obtained from the River Vyrnwy which is situated on the lines of route to the metropolis.

"It is proposed to convey the water from Bala through a series of iron pipes sunk to a depth sufficient to protect them from the action of the frost, along the sidings of the Great Western Railway to Stanmore, where the reservoirs should be on a scale adapted to provide for a storage of water equal to forty days' supply. These should consist of one or more large reservoirs and ten smaller ones. The large reservoirs would be capable of holding three thousand million gallons, or 30 days' supply, and would be lined with brick or stone The ten smaller ones, lined with white glazed brick, would each be calculated to contain 100 million gallons. The space required for those reservoirs would be 500 to 600 acres, for the large ones according to depth, and 25 acres for each of the smaller ones. The water would be delivered into the large reservoirs as pure as its source, thence it would pass through a system of filtration of approved character into the smaller reservoirs in a condition of absolute purity. These reservoirs being 250 feet above the Bank of England, the water on reaching London would be conveyed through the existing mains of the water companies at high service level.

"*General Remarks.*—Had Bala Lake existed at Stanmore, instead of North Wales, it would, doubtless, long ago have formed the source of the London water supply. If it is approved as a source of supply, it is simply an engineering question how to convey the water for the use of the metropolis free from pollution in the most effectual and economical way. By adopting the sidings of the Great Western Railway as the route, the following advantages would be obtained:

"1. The right of way for almost the entire route would be secured by one negotiation.

"2. Land otherwise of no value would be utilized without detriment either to it or to the property of the railway company.

"3. All the plant required would be delivered by the railway company at the places where it would be laid.

"4. The telegraph system would be available in case of any accident to the pipes.

"5. There would be great saving in the time required for the construction, and also great saving in the cost.

"By making the reservoirs at Stanmore a sufficient level would be obtained to supply the high service to London without pumping, the cost of which, at present, with filtration, is about £100,000 (one hundred thousand pounds) per annum. By the use of white glazed bricks for the lining of the smaller reservoirs, facilities for quickly and thoroughly cleansing them would be obtained. In short, pure water would be delivered from them as from a china basin."

Russian Surveys in the Balkan Peninsula.—The geodetic and astronomical operations carried on by the Russians in the Balkan Peninsula, which in 1877 and 1878 covered the central part of Bulgaria and Roumelia, were, in 1879, extended eastward as far as the sea, and west over the Rhodope mountains as well as along the new Serbo-Turkish frontier to Novi-Bazar. A trigonometrical network thus now covers Bulgaria and Roumelia as well as a part of the Turkish territory. On the Serbo-Turkish frontier a strip 30 versts broad, and from the Bulgarian boundary to Novi-Bazar 175 square versts long, has been triangulated. Over 150,000 square versts, 1,300 points, have been fixed as sure bases for a special topographical map of Bulgaria, Roumelia, and Turkey from San Stefano in the south upwards. The geodetic network is connected both with the

Russian meridian measurements and the Austrian Survey. The calculations are not yet completed for all points, yet the leader of the operations, Colonel Lebedew, has put together a relief of the Great Balkan from the sea to the Servian boundary, and the Little Balkan, with its off-shoots, to the valley of the Maritza. From this it is seen that the crest of the Balkan, from the Black Sea to Kotel, is nowhere more than 3,000 feet above the sea level; from Kotel to the meridian of Selwi it rises from 3,500 feet to 4,900 feet; further to Zlatitza it has nearly everywhere a height of from 5,600 feet to 6,300 feet, its highest point rising to 7,000 feet; the last section, from Zlatitza to the Servian frontier, has a height of from 4,900 feet to 6,300 feet, without any very prominent summit. The highest point of the Balkans, the Jümrüktschal, 7,830 feet high, lies 12 versts north of Karlovo (1,260 feet above sea level). The Rhodope mountains are mostly 5,600 feet above the sea, the highest point not exceeding 7,000 feet. The Rilo mountains exceed the Balkans in height, their three highest points, Oleni Wrch, Popowa Schapka, and Segmentski Wrch, rising to more than 8,400 feet above the sea. Mount Witosch, isolated over the plain of Sofia, rises over 7,000 feet, and stands only second to Jümrüktschal in the Balkans. In general, the surface of the Balkan Peninsula rises in the direction from the Black Sea towards the west very considerably, so that *e. g.*, the valley of the Isker at Samakow, 3,360 feet high, lies higher than the crest of the Balkans between the Black Sea and Kotel. To the network of telegraph observed places have been added in 1879 over 20 astronomically observed points, so situated that they form, with the fixed points of 1877 and 1878, four circles, which establish a reciprocal control over the operations. In Servia, the position of Nisch has been ascertained, and will connect the operations with those of the Russians by means of the difference of longitude between Rustchuk and Kishinew. This year Colonel Lebedew will further ascertain the difference between Kishinew and Rostov, on the Don. On the topographical operations from 1877 to November, 1879, 100 topographers, divided into two main parties were engaged. One, under Colonel Shdanow, completed in 1878-79 the east part of Bulgaria and Eastern Roumelia, 14,700 square versts; the other, under General Ernefeld, from 1877 to 1879, completed 82,350 square versts in these difficult western part and on Turkish territory in the Midia-Adrianople-Dedeagatch section. Along the boundary between Bulgaria, East Roumelia, Servia, and Turkey, a strip ten versts wide was measured in 1879. These boundaries run mostly at considerable heights (over 5,000 feet) from summit to summit, along the water-parting and mountain crest. The plates of the survey in Eastern Bulgaria were ready to be laid before the Russian Emperor on April 19; the sheets of West Bulgaria will be ready in November next. The maps will afterwards be published in heliography.—*The Times.*

THE BALTIC AND GERMAN OCEAN CANAL.—The project for this canal, which has during the last thirty years been more or less under consideration, has lately received a new impulse through an interesting pamphlet published by Mr. Dahlström, who points out the great advantage of a canal connecting these two seas, and as the most suitable location the line between the Bay of Kiel, on the Baltic, and the town of Brunsbüttel, on the German Ocean, is recommended. The canal would have a width at water level of 164 feet, at bottom of 65 6 feet, and a depth of 21 feet 4 inches, but by a special arrangement of locks the depth could be temporarily increased to 24 feet 6 inches, which would allow the largest vessels afloat to pass the canal. These dimensions are but little below those of the general section of the Suez Canal, which is 110 feet wide at water level, 72 feet at bottom, while the depth varies from 24 feet to 26 feet. By reducing the dimensions to the figures quoted above, Mr. Dahlström calculates that the cost of the canal may be reduced by about £750,000 as compared to previous estimates, and puts the total expenditure at £3,750,000. Of this sum it is proposed that the Government provide one-fifth, while the remainder is contributed by private enterprise. The number of ships now passing the Sound, between the island of Zealand and Sweden, amounts, according to Mr. Dahlström, to 36,670 per annum; of these 9,100 are steamers, and if only two-thirds, or say 24,500 of the vessels will use the new canal, which for steamers effects a saving over the old route of thirty hours, and for sailing vessels of four days, a small tax per ton will pay a good interest on the invested capital. The preliminary works for this canal are making good progress under Mr. Dahlström's direction. Borings along the route of the proposed canal are completed, and are said to have given very satisfactory results, while the surveying operations are expected to be completed during this autumn, when plans and specifications will be prepared, and submitted for Government approval.

ORDNANCE AND NAVAL.

VELOCITY OF PROJECTILES IN GUNS.—The methods that have been tried for ascertaining the law of motion of a projectile in the bore of a gun (with a view to finding the law of pressures developed) give only a small number of points of the curve of spaces traversed in given times, and they involve perforation or other injury to the walls of the gun, so that they are applicable only to large pieces. A new and ingenious method, advantageous in these respects, has been contrived by M. Seibert. In the axis of a cylindrical hollow projectile he fixes a metallic rod of square section, which serves as guide to a movable mass. This mass, or runner, carries a small tuning-fork, the prongs of which terminate in two small metallic feathers, which make undulatory traces on one of the faces of the rod (blackened for this purpose with smoke) as the runner is displaced along the rod. The runner, it will be understood, is situated at first in the front part of the projectile, and while the latter is driven for-

ward remains in place, the rod of the projectile moving through it. The escape of a small wedge between the prongs of the fork at the moment of commencing motion sets the fork in vibration. It can be easily shown that, owing to the very high speed imparted to the projectile, the displacement in space of the inert mass, through friction and passive resistances, which tend to carry it forward with the projectile, is such as may be quite neglected. So that the relative motion of the mass recorded by the tuning-fork may be considered exactly equal and opposite to the motion of the projectile. A study of the curves produced guide to the laws of the motion and of the pressures developed by the charge. Evidently the motion of a projectile as it buries itself in sand or other resistant medium may be similarly determined.

The Boilers of the Livadia.—Those engineers who hold that steel is not a good material of which to make boilers, will find support for their opinions in the failure of the boilers of the Czar's yacht Livadia. This vessel was to have had eight main boilers of steel. Six of these were finished and ready for the hydraulic test of 150 lb. per square inch. On the tpump being set to work the first boiler split through the solid steel plate, the longitudinal crack being about 3 feet long, the pressure reached being 140 lb. The whole of the boilers were, we understand, thereupon condemned. It was determined, however, to proceed with the test, and three more boilers were easily burst with pressures varying, we are told, between 80 lb. and 140 lb. The plates were of Cammel's steel. This experiment will go far to cause the total rejection of steel by shipowners as a material for boilers. It is also stated that experiences recently acquired are all against steel as regards the durability of furnace plates; and some eminent marine engine builders will not employ it on any terms. So far nothing more is known concerning the break-down of the Livadia's boilers than the broad facts as stated above, but the subject is so important that it is to be hoped Messrs. John Elder & Company will supply full information on the subject.

Experiments in Ship-building. The Lines and the Speed of the "Livadia."—All persons interested in naval architecture will watch, with some curiosity, for the details of the actual performances of the Livadia, the anomalous raft-palace recently built for the Czar, in the Fairfield Yard at Govan, on the Clyde, and launched on the 7th of July. The Livadia is the latest modification of the famous circular, or rather soup plate shaped, craft invented by the Russian Admiral Popoff. It consists, in fact, of a sort of raft, in the form of a turtle, or, as the designer, Captain Goulæff, prefers to call it, a turbot, with a palace on its back. The daily papers have given such full details of this yacht — the *Times* having even produced a kind of diagram representing it—that it is unnecessary to reproduce them here. But it is desirable to call attention to those main principles of structure as to which the Russian naval architect entirely ignores all rules consistent with the best results of experiments like those made for our Admiralty by Mr. Froude, to say nothing of the long labors of Mr. Reed and Mr. Scott Russell. The "wave-line theory" is altogether ignored by the builders of the Livadia. The possibility of floating over waters liable to stormy disturbances, without offending a squeamish stomach, has been the great point at which Captain Goulaeff aimed. The experience of the Great Britain, the Great Western, and the Great Eastern, has shown that great steadiness, as regards the pitching motion of a ship, may be attained by making the keel long enough to ride on the crests of two or three waves at a time. It may be taken as a corollary of this proposition, that if the bottom of a craft be made wide enough, immunity from rolling may be attained in the same way. The only drawback to this theory is, that the proportions which tend to give a lateral stability are incompatible with speed; at all events, without the incurring of an enormous expense. It will be seen at a glance that the Russian naval architect is not ignorant of this fact. The length of the Livadia is 230 ft., while what may, in courtesy, be called its beam, is 153 ft. The displacement is calculated at 4,000 tons, spread over an oval area of 14,500 square feet. The proportions of the length and beam of modern ocean steamers range from 6.38 to 1, to 10.61 to 1; and the resistance to the passage of a ship through the sea is taken, by the usual rule adopted by the French naval architects, as proportionate to the area of the midship section, multiplied by the cube of the velocity. The English rough rule gives two-thirds of the displacement, multiplied by the cube of the velocity. The velocity which the Livadia is expected to attain is stated at fourteen knots an hour. That of our recent war ships is eighteen knots an hour; and the speed attained by an Indian dispatch boat for the Orissa canals, built by Thornycroft, of London, has been minuted at 24.61 miles per hour. As resistance is now regarded, we have the practical rule, that the indicated horse-power employed in a steamer is proportionate to the cube of her speed. The cube of 18 is more than double the cube of 14 (being respectively 5,832 and 2,744); so that the resistance overcome by the Livadia, in proportion to its midship section, is less than half that overcome by such an English man-of-war as the Iris, as far as is due to the speed maintained. But the horse-power provided per ton is more than three-fold in the case of the Livadia. The indicated horse-power proper to give the speed of fourteen knots an hour to a vessel of this length and beam, taking the draught of water as 6 ft., according to the practical formula given by Mr. William Allan, in his "Shipowner's and Engineer's Guide," is under 8,000 h.p. That provided by Captain Goulaieff is 10,500 h.p. The first is 2 h.p. per ton of displacement. The second is 2.625 h.p. per ton of displacement. The proportion in the English war ships may be taken at seven-eighths of a horse power per ton of displacement. Thus for a speed which gives less than half the resistance overcome by such vessels as the Iris, more than three times the indicated horse-power per ton is provided. In other words, the cost of

fuel for the steam propulsion of the Livadia will be more than six times as much as that required for a vessel of normal proportions.

The calculations given of the displacement of the Livadia do not come out quite exact. If a weight of 4,000 tons is distributed over an area of 14,500 feet, there will be 3.625 square feet of surface per ton; and taking the weight of water at 62 lbs. per cubic foot, we require 10 ft., instead of 5* ft., of immersion to balance the weight of the vessel. But the screws are said to draw 16 feet of water, or 10 ft. more than the intended draught of the vessel. There is good reason to suppose that such a disposition will naturally diminish the speed of the craft, as in the case of towing a rope through the water.

Nor is this the only point to be regretted as to the arrangements for propulsion. The battle between floatation and engine-power is one as to which, by the use of steel, and the constant improvements in engines, the advantage is tending to the side of the latter. In an enormous flat-bottomed craft, if in anything, it might be hoped that so much power might be placed as to produce the known, but not thoroughly understood phenomenon, of the rise of the vessel, and its skating or sliding over the surface of the water—as a canal-boat will do if tugged at a great speed. We can conceive such a result to have been possible in the case of the Livadia, if the efforts of the engineer had been directed to produce it. We should anticipate that the deep submersion of the screws will be fatal to such a hope. Any way, we shall look with interest to the test of actual navigation, and shall be very glad to hear of any result of use to the shipbuilder from the construction of this abnormal floating palace.—*The Builder.*

BOOK NOTICES

Publications Received.

Through the kindness of Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following selected Papers:

"The Temnograph," by Alexander Manson Rymer-Jones, A. M. I. C. E. "The Chile Vein Gold Works, S. A.," by George Attwood, F. G. S. "A New Snow Plough," by John Newman, A. M. I. C. E. "Rural Water Supply," by Thomas Sullock Stooke, A. M. I. C. E. "The Calder Viaduct," by David Munro Westland, M. I. C. E. "The Hydrogeology of the Lower Greensands of Surrey and Hampshire," by Joseph Lucas, F. G. S. "Removal of Sunken Rocks in Brest Harbor," by H. Willotte. "Abstracts," Vol. LXI., Part 3. "Bulletin of the American Geographical Society," No. 4, 1879. "National Quarterly Review," July. "Journal of the United States Association of Charcoal Iron Workers."

Traité Elementaire de la Pile Electrique. Par Alfred Niaudet. Paris: J. Baudry. For sale by D. Van Nostrand. Price $2 00.

This is a second edition of a work pretty well known. The work treats first of the construction of a great many kinds of batteries, and of the chemical sources of the electro-motive energy in each kind.

The peculiarities of the leading varities, together with a special statement regarding the kind of service each is best fitted for, is a valuable feature of the treatise.

Tables of the resistances of battery solutions, and of the electro-motive force of batteries are given at the end of the volume.

Sixty-five excellent wood cuts embellish the text.

Manual of Hydraulic Mining for the Use of the Practical Miner. By T. F. Wagener, E. M. New York: D. Van Nostrand. Price $1 00.

This is a book for the pocket, and contains only such practical knowledge as is of constant service in the field.

The contents embrace: General Physical Conditions, General Methods of Placer Mining, Directions for the Miner, the Properties of Water, Construction of Water-Ways, Flow of Water in Flumes and Ditches, Iron Piping, Nozzles and Discharge, the Sluice.

The methods of applying the rules for computation are illustrated with exceeding fullness by examples worked out.

On the Mechanical Equivalent of Heat. By Henry A. Rowland. Cambridge University Press.

This work is a collection of the author's papers reprinted from "The Proceedings of the American Academy of Arts and Sciences." Besides the essay named in the leading title of the book, two others are also given: The Variations of the Mercurial from the Air Thermometer, and The Variation of the Specific Heat of Water.

The essays are of the greatest value to students of physics, not only from the presentation of the facts, but chiefly because they exhibit the method of an eminent worker, both in his way of experimenting, and also in his way of deducing the laws from the observed phenomena.

An Elmentary Treatise on the Differential and Integral Calculus. By Edward A. Bowser, Professor of Mathematics and Engineering in Rutger's College. New York: D. Van Nostrand. Price $2 25.

The flattering reception accorded to Prof. Bowser's Analytical Geometry, would seem to justify the expectation of an equally ready acceptance of this later book.

The merit acknowledged in the former book, of a clear logical presentation of the science as recently developed, and divested of the portions not serviceable to the learner, is certainly a characteristic of the last work of this author.

Teachers and students who have found their wants served by the first book, will, we are confident, welcome the calculus as a fitting supplement.

The two branches of the calculus are presented complete in a 12mo of 395 pages.

Contents: Part 1—Differential Calculus—1. First Principles; 2. Differentiation of Algebraic and Transcendental Functions; 3. Limits

—Derived Functions; 4. Successive Differentials and Derivatives; 5. Development of Functions; 6. Evaluation of Indeterminate Forms; 7. Functions of two or more Variables, and Change of the Independent Variable; 8. Maxima and Minima of Functions of a Single Variable; 9. Tangents, Normals and Asymptotes; 10. Direction of Curvature—Singular Points—Tracing of Curves; 11. Radius of Curvature—Evolutes and Involutes—Envelopes.

Part II.—Integral Calculus—1. Elementary Forms of Integration; 2. Integrations of Rational Fractions; 3. Integration of Irrational Fractions by Rationalization; 4. Integration by Successive Reduction; 5. Integration by Sines—Successive Integration—Integration of Functions of two Variables and Definite Integrals; 6. Length of Curves; 7. Areas of Plane Curves; 8. Areas of Curved Surfaces; 9. Volumes of Solids.

MISCELLANEOUS

An Intensified Electro-Magnet.—Dr. Stone recently exhibited before the Physical Society a very interesting electromagnet of novel construction, and based on a principle which will probably be applied with advantage in the construction of electro magnets for dynamo electric machines and telegraphic apparatus. It is known that electro-magnets enclosed in jackets of soft iron, are far more powerful than when the copper wire of the coil is unenclosed. In fact, the iron jacket, like the second armature or diaphragm in M. Ader's form of Bell telephone recently described by us, has the effect of exalting the magnetic power of the poles. Dr. Stone does not employ a soft iron jacket; but, instead of using copper wire to wind the bobbins, he uses best charcoal-annealed iron wire about $\frac{1}{8}$ in. in diameter. Four wires are wound on in parallel circuits, and the current is split up among them in "multiple arc." They are insulated from each other by paraffine wax. By this felicitous arrangement the lifting power of Dr. Stone's large magnet is, with a battery of five or six Bunsen cells, inincreased fourfold.

In continuing his researches on the welding of solid bodies by pressure, M. Spring has subjected to various strong pressures—up to 10,000 atm.—more than eighty solid pulverized bodies; this, according to *Nature*, was done in vacuo, and in some cases at various temperatures. The results are highly interesting. All the crystalline bodies proved capable of welding, and in the case of bodies accidently amorphous the compressed block showed crystalline fracture; crystallization had been brought about by pressure. Softness favors the approximation of the particles and their orientation in the direction of the crystalline axes. The amorphous bodies, properly so called, fall into two groups, one of substances like wax—*ciroid* bodies—which weld easily, the other of substances like amorphous carbon—*aciroid* bodies—which do not weld. The general result is that the crystalline state favors the union of solid bodies, but the amorphous state does not always hinder it. M. Spring says the facts described do not essentially differ from those observed when two drops of a liquid meet and unite. Hardness is a relative, and one may even say subjective, term. Water may appear with a certain hardness to some insects, and if our bodies had a certain weight we should find the pavement too soft to bear us. Again, prismatic sulphur is changed by compression to octahedric sulphur; amorphous phosphorus seems to be changed to metallic; other amorphous bodies change their state, and mixtures of bodies react chemically if the specific volume of the product of the reaction is smaller than the sum of specific volumes of the reacting bodies. In all cases the body is changed into a denser variety, whence may be inferred that the state taken by matter is in relation to the volume it is obliged to occupy under action of external forces. This is merely the generalization of a well-known fact. Some curious results are deduced from it. The researches described have important bearings on mineralogy and geology.

Messrs. Siemens & Halske have, it is said, laid before the municipality of Berlin another project for the establishment of electric railways in that town. They propose that all the railway termini in Berlin, and the stations of the metropolitan railway, should be placed in communication by the electrical railway. It is proposed also that a line should be constructed from the Skalitzerstrasse to the terminus of the metropolitan railway and to the Zoological Gardens, passing by the stations of Potsdam and Anhalt, and that a second line should be laid between the Brandenburg Gate and Charlottenburg.

The explosive disintegration of toughened glass tumblers forms the subject of further correspondence in *Nature*. Mr. T. B. Sprague writes that a member of his family was about to take a seidlitz powder, and had poured the contents of the blue paper into a tumbler of toughened glass half filled with cold water, and was stirring it gently to make the powder dissolve, when the tumbler flew into pieces with a sharp report. The bottom of the tumbler was not altogether fractured, but cracked into a number of little squares, which could be separated readily. Another correspondent says: "In a hot room I had just finished what is usually called a 'lemon squash,' *i. e.*, the juice of a lemon and a little white sugar, with a bottle of soda-water, a lump of ice being put into the mixture. I was talking at the time, and so held the empty glass with a spoon in it in my hand for a second or two, when it suddenly went off in my hand into thousands of pieces, none larger than an inch or so. I picked up one of the largest and thickest pieces, and found it to be so thoroughly disintegrated that I broke it up with my fingers into about a hundred small pieces, and might have done more."

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THE ERRORS OF THE ZEUNER DIAGRAM AS APPLIED TO THE STEPHENSON LINK MOTION.*

By WILLIAM D. MARKS, Whitney Professor of Dynamical Engineering, University of Pennsylvania.

I. Introduction.

The mathematical elegance of Professor Gustav Zeuner's *Treatise on Valve Gears* is due to the fact that he has shown that the equation representing the distance of a slide valve, controlled by an eccentric or by means of a link, is in all cases with greater or less approximation the polar equation of a circle. Deservedly his work has met with a most gratifying acceptance from all educated engineers, as not only being the most correct, but also the only method which, without the aid of models or templates, enables the practioner to devise and study any desired form of valve gear.

The lack of practical knowledge on the part of most of the students of engineering in the University of Pennsylvania, rendered a working model necessary to the full comprehension of the valve diagram, and the attachment of a drawing board which should turn synchronously with the crank, upon which a pencil attached to the top of the slide valve should mark the curve (approximately a circle) showing its distances from its central position for each position of the crank, naturally suggested itself.

As shown in the drawing (Fig. 1) upon the top of a standard behind the section of the cylinder a pulley of equal size with the crank shaft was connected with the crank shaft by means of a steel saw band running upon thin gutta percha strips glued to the shaft and pulley surfaces. This steel band was kept very taut by means of a stretching pulley about the middle of its length.

Upon the end of the pulley shaft and just back of the valve a drawing board was so attached as to permit a pencil, attached to the valve and kept pressed against the paper stretched upon the drawing board, to trace the curve, showing the distance of the valve from its central position.

So elaborate an apparatus as this would not have been needed, had it not been deemed desirable to avoid all possible causes of obscurity in the students' minds.

Had the drawing board been attached directly to the crank shaft, and a rod having a pencil in the end been attached to the link block, or any point on the valve or valve stem, and carried back to the center of the board, it would have

* The drawings for this article were made by Mr. G. H. Lewis, a graduate of the Department of Dynamical Engineering, and used by him as part of a thesis.
The mathematical treatment is my own. Mr. Lewis' drawings have been somewhat added to, in order to give graphical methods of determining the errors of the diagram. I am indebted to Mr. Lewis for many ingenious and thoughtful suggestions, and much accurate and painstaking work in tracing the diagrams.—W. D. M.

been more serviceable for scientific purposes, as eliminating some of the possible sources of error due to the imperfections of the model.

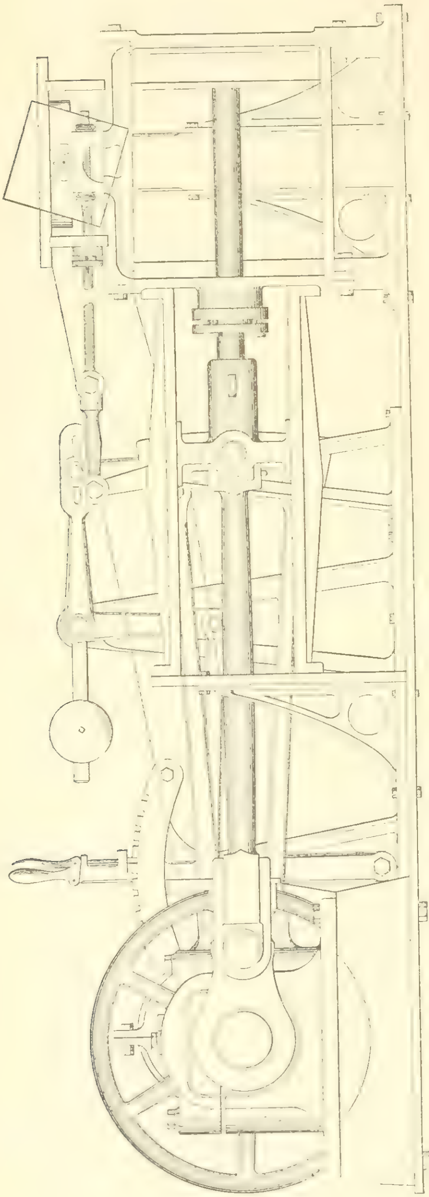


Fig. 1.

This model was constructed of iron, brass and mahogany, and every possible precaution was taken to obtain rigidity and avoid shrinkage; it was constructed full size from the dimensions stated by Zeuner in his Treatise on Valve Gears, page 78.

Eccentricity $= r = 2.36$ inches.
Angular advance $= \delta = 30°$.
Length of the eccentric rods
$= l = 55.1$ inches.
Half length of the link $= c = 5.9$ inches.
Outside lap $= e = 0.94$ inches.
Inside " $= i = 0.27$ "

Open eccentric rods and equal angles of advance were taken. The link was so attached to the eccentric rods as to permit the link block to be placed immediately in front of the ends of the eccentric rods; in other words, so that the variable distance u of the link block from the center of the link could at its maximum be made equal to the half length of the link c.

This form of link is shown in Fig. 2 a.

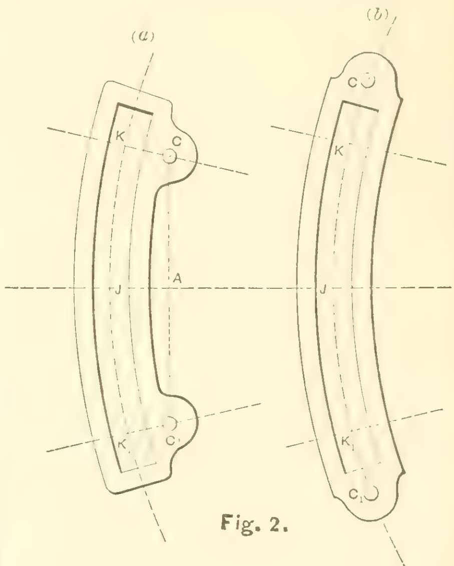


Fig. 2.

The diagrams taken upon this model clearly showed that some greater sources of error existed than the so-called "Missing Quantity" of Zeuner.

Acceptance of authority is a great preventive of advancement of knowledge, and it will be our task to show clearly what points have been overlooked by Professor Zeuner, with, we hope, the result of making even more clearly understood this construction, so simple in its mechanism and so intricate in its action.

II. The Simple Slide Valve. Consideration of the Missing Quantity in the Simple Slide Valve. Setting Valve for Equal Leads Equivalent to Altering the Laps of the Valve.

For the sake of simplicity let us first consider the simple slide valve.

On page 11 of his Treatise on Valve Gears, Zeuner gives for the distance of a simple slide valve from its center of motion ξ

$$\xi = r \sin(w+\delta) + \frac{r^2}{2l} \sin(2\delta + w) \sin w$$

The first term of the second member of this equation is the polar equation of a circle, with the origin in its circumference and its diameter forming an angle equal to δ; with the axis of ordinates OY (see Fig. 3) w is the angle which the crank forms with the axis of abscissas OX. All of this can readily be understood from the explanations given in the book.

It is with the second term of the second member—"the missing quantity"—that we shall have particularly to deal, for Zeuner has considered it as inappreciable in most cases, which is not practically true, for many cases occur in which of necessity the eccentric rods are comparatively short.

Dr. Zeuner fixes the central position of the slide valve by taking the mean of the two positions of the valve when the crank is on its dead points; he does this on the assumption that the valve will be set for equal leads, which is always the proper method.

This central position differs from the true central position by a quantity $=\frac{r^2 \cos^2\delta}{2l}$ for the true central point of the valve travel is a mean between the extreme positions of the valve and further away from the crank shaft, a distance equal to the above-stated quantity, therefore at one extreme the valve's distance from Zeuner's center $= r + \frac{r^2\cos^2\delta}{2l}$ and at the other extreme $= r - \frac{r^2\cos^2\delta}{2l}$.

If now we can convert the missing quantity into a function of the theoretical valve distance, from its center for equal leads (Zeuner's center), we can much more conveniently lay down the irregular curve of the valve circle for the case of a short eccentric rod.

According to the diagram $\xi = r\sin(w+\delta)$ Page 43 Z. T. V. G.* the missing quantity is given as

$$z = \frac{r^2}{2l}\left[\cos^2\delta - \cos^2(w+\delta)\right]$$

or

$$z = \frac{r^2}{2l}(\cos^2\delta - 1) + \frac{r^2\sin^2(w+\delta)}{2l}$$

or

$$2lz = r^2(\cos^2\delta - 1) + r^2\sin^2(w+\delta)$$

Letting $C = r^2(\cos^2\delta - 1)$ and substituting ξ for its value, we have

$$\xi^2 = 2lz - C$$

the equation of a parabola whose ordinates are the theoretical travels of the valve from its center of motion, and whose abscissas are the missing quantities for the same.

The radius of curvature of this parabola at its vertex $= \frac{1}{2}$ the latus rectum or parameter, and is equal to l the length of the eccentric rod, and we can substitute an arc of a circle with the radius l for this parabola without appreciable error.

For the travel $\xi = o$

$$z = \frac{C}{2l} = \mp \frac{r^2}{2l}\sin^2\delta$$

For $\xi = r$

$$z = \pm \frac{r^2}{2l}\cos^2\delta$$

For $z = o$

$$\sin^2\delta = \sin^2(w+\delta)$$

Therefore $\qquad w = o$

That is to say, the "missing quantity" disappears on the dead points since the valve is *actually set for equal leads.*

To lay down the actual curves of valve travel, the "missing quantity" being taken into account.

Fig. 3. With a radius OL_0 and the center O describe an arc L_0L to intersection L with the diameter of the valve circle OP_0. At the point O, and at right angles with OP_0, draw the indefinite line OZ.

With a radius of compass $=l$, and

* Abbreviation of Zeuner's Treatise on Valve Gears.

with the center on the line OZ, describe through L and L_1 the arc QLL_1Q_1. The ordinates to this arc from the line OP_0 measure in quantity and direction the values of the "missing quantity," which must be added to or subtracted from the theoretical radius vector, in order to obtain the true curve of the motion of the valve.

Fig. 3, for the purpose of showing an extreme case, has been laid down to scale as follows:

Eccentricity$=r=2$ inches.
Angular advance$=\delta=30°$.
Outside lap$=e=0.82$ inches.
Width of port$=a=0.75$ inches.
Length of eccentric rod$=l=8$ inches.

The construction for the missing quantity, for the sake of clearness, has all been added in heavy lines.

The effect of the "missing quantity" when considerable enough to be noticed, is when the piston head moves towards the crank shaft, the cylinder being at the right hand.

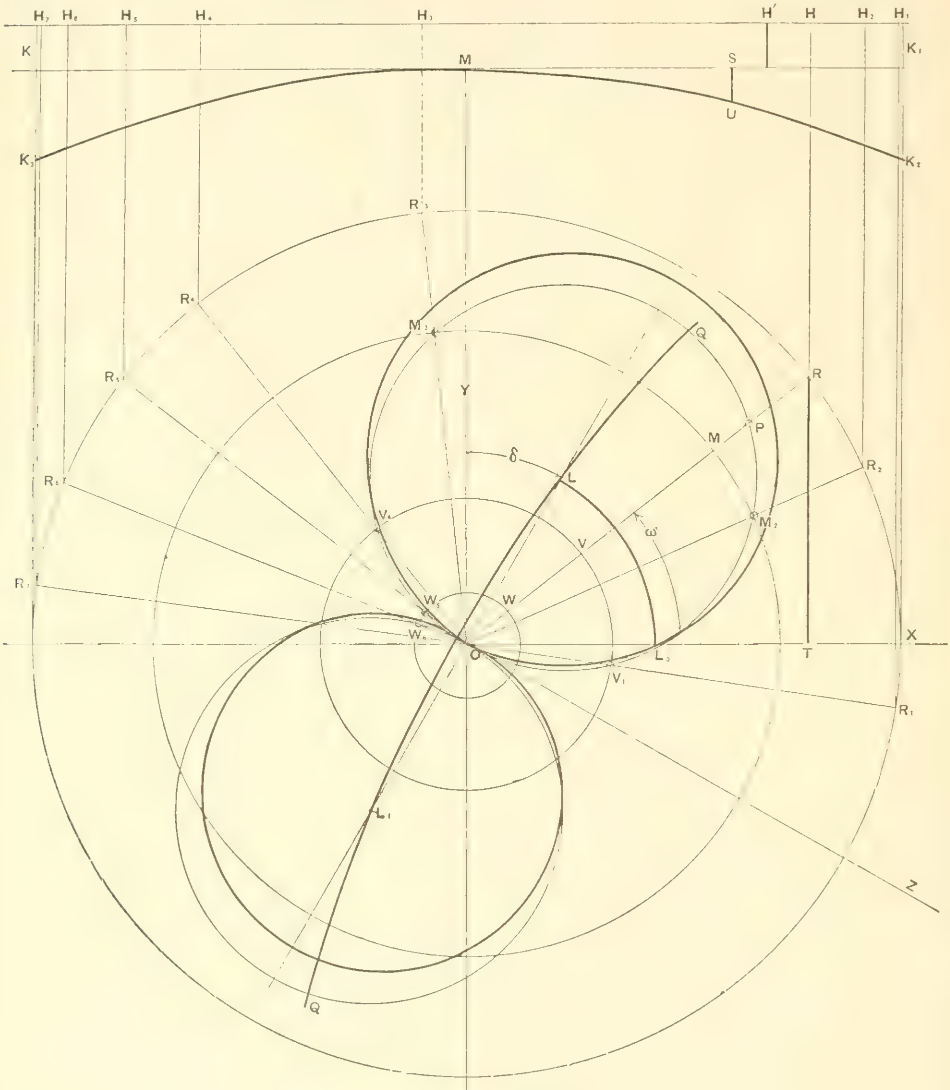


Fig.3

(1) To delay slightly the pre-admission of steam.
(2) To increase the over-travel.
(3) To hasten the cut off of the steam (very slightly).
(4) To hasten the compression of the steam.
(5) To hasten the release of the steam.

When the piston head moves away from the crank shaft.

(1) To hasten the pre-admission.
(2) To diminish the over-travel.
(3) To delay the cut off (very slightly).
(4) To delay the compression.
(5) To delay the release.

A glance at the diagram at once reveals the fact that equalizing the lead very nearly equalizes the cut off.

It is only when the valve is set for equal extreme travels from the center that different laps are required. No attention has been paid to the variation in position of the piston due to the obliquity of the connecting rod.

III. THE PISTON'S POSITION.

The effect of the obliquity of the connecting rod is to keep the piston nearer to the crank shaft when it is moving away from it, and to draw it closer to the crank shaft when it is moving towards it, than it would be if the connecting rod was constantly parallel to the center line of the cylinder.

At the dead points, the connecting rod being in the center line of the cylinder, this action ceases.

Letting w = angle of the crank
" R = radius " "
" L = the length of the connecting rod.

We would have, if the connecting rod were constantly parallel to the center line of the cylinder, for the space passed over by the piston head = S

$$S=(1-\cos w)R$$

and when we take the obliquity of the connecting rod into consideration

$$S_1=R(1-\cos w-L\left(1-\frac{\sqrt{L^2-R^2\sin^2 w}}{L}\right)$$

Then for the difference d between the two positions we have

$$d=S-S_1=L\left(1-\frac{\sqrt{L^2-R^2\sin^2 w}}{L}\right)$$

or expanding

$$d=\frac{R^2}{2L}\sin^2 w \quad \text{approximately.}$$

Fig. 3. The positions H_1 to H_7 can be corrected by laying down in the opposite direction from the cylinder—from the points as already found the values of d.

It will be observed that the equation for d is the equation of a parabola whose semi-latus rectum is equal to L. Further, for $w=o$ or 180° $d=o$. If for this parabola we substitute the osculatory circle of a radius L to its vertex, we are practically close enough.

If now with a radius of compass = L, with one point in M and the other on the line YO bisecting the cylinder we describe the arc K_2K_3, we have, with sufficient approximation, the desired parabola.

Taking off for the position OR of the crank the distance RT = R sin w, and laying it off from M to S we have the correction SU of the position of the piston H, which, if we consider the cylinder at the right hand side, should be laid off to the left of H, giving the true position of the piston head at H′.

Thus we can lay down graphically the actual positions of the piston, and the true distances of the slide valve from its center of motion, *when set for equal leads* for every position of the crank, and for any proportions of the mechanism.

For the sake of emphasis, we again repeat: *Different laps are not necessary when the valve is set for equal leads, when the piston position is disregarded.*

Altering the laps will alter the leads. If the piston position is regarded and the alteration in the leads is disregarded for the sake of a very accurate cut off, the lap should be shortened on the side towards the cylinder, and lengthened on the side away from the cylinder. These amounts can be determined from the diagram.

It is only in the case of a very short connecting rod that such a procedure is necessary; short eccentric rods do not require it.

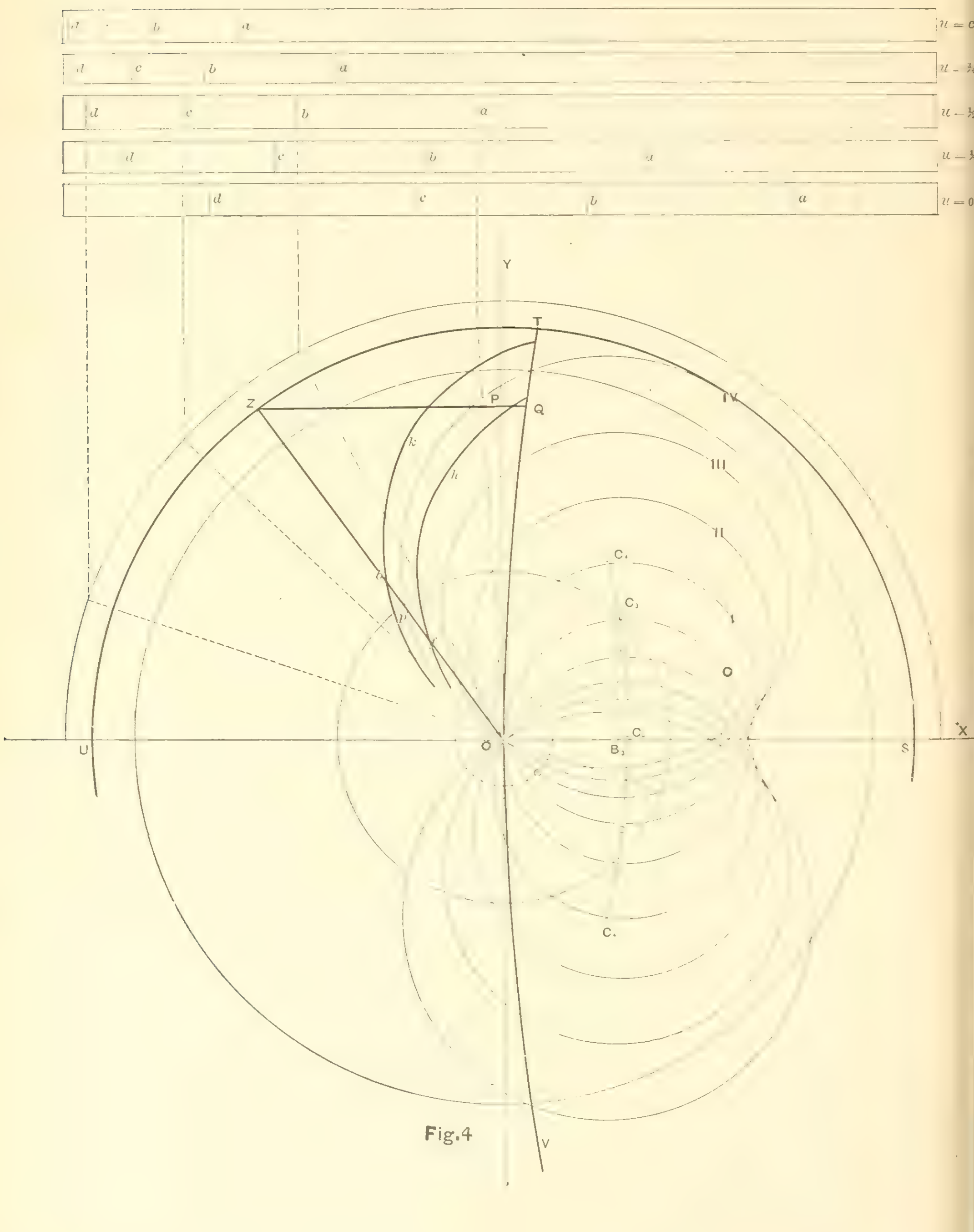


Fig. 4

IV. The Stephenson Link Motion. Error Due to an Imperfect Mode of Attaching the Link to the Eccentric Rods.

On pages 56 to 98 of Z. T. V. G. the Stephenson Link Motion is very fully treated for both open and crossed rods, and for both forms of link, shown in Fig. 2 *a* and *b*, no distinction being made between them.

In Fig. 2 *a*, it will be observed that the rods are attached on the concave side at the points C and C_1, introducing an error which we will next endeavor to determine.

Fig. 4 is the Zeuner diagram, carefully laid down for the dimensions already given of the model, on which was used a form of link shown Fig. 2 *a*.

The method of making the slide valve describe its own diagram has already been explained. It is only necessary to add that as the drawing board turns synchronously with the crank, that the valve circles (curves) will both be on the same side of the origin instead of on opposite sides, as drawn for the sake of clearness in Fig. 3.

The object of making the link of the form Fig. 2 *a* is two-fold. First, to reduce the eccentricity, second, to enable us to place the valve wholly under the control of one eccentric rod.

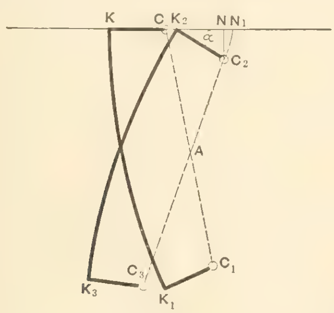


Fig. 5.

Fig. 5 is a center line sketch of Fig. 2*a*, similarly lettered; it will be observed that as the suspended link sweeps to and fro with a scythe-like motion, the line KC forms an angle with the horizontal line KN_1, which is approximately equal to the angle a, which the chord of the link forms with the vertical.

The value of $\sin a$ is given with very close approximation on page 61 equation (11) Z. T. V. G.

As our only object is to point out an error which can be avoided, we will only make use of the principal term of this quantity, and take

$$\sin a = \frac{r}{c} \cos \delta \sin w.$$

Let us denote the missing quantity due to this error by $z_1 = NN_1$, its effect being to keep the link closer to the crank shaft except where it equals zero.

Let $KC = q$

$$NN_1 = z_1 = q(1 - \cos a) =$$

$$q\left(1 - \sqrt{1 - \frac{r^2}{c^2} \cos^2 \delta \sin^2 w}\right)$$

or expanding the quantity under the radical, and neglecting terms containing greater than the second power of the circular functions, we have

$$z_1 = \frac{qr^2}{2c^2} \cos^2 \delta \sin^2 w$$

For $w = 90°$ this quantity is a maximum, and for $w = o°$ it is equal to zero. That is, it does not appear in the lead when the valve is set for equal leads, but it does attain its maximum near the point of usual cut off, and is particularly pernicious there and at the point of exhaust closure. The reason that it has remained unperceived hitherto is probably because it does not appear in the lead.

Transposing, we have

$$r^2 \sin^2 w = \frac{2c^2}{q \cos^2 \delta} z_1.$$

The equation of a parabola whose ordinates are $r \sin w$ and whose abscissas are z_1, its semi-latus rectum is $\frac{c^2}{q \cos^2 \delta}$ which is also the radius of curvature of the osculatory circle to its vertex.

A moment's reflection will convince the reader that the error due to Zeuner's missing quantity is inappreciable (where of any consequence) in the present case. See Fig. 3 and explanation.

To determine the error z_1. Through O (Fig. 4), with a center on OX produced,

describe an arc of a circle TOV with a radius$=\frac{c^2}{q\cos^2\delta}$. With O as a center and the radius r describe an arc STU. Draw any position of crank as OZ to intersection Z with the arc STU. Parallel to OX draw through Z the line ZQ. which is the radius of the arc VOQT.

Laying down after the manner described, the arcs *bk fh*, we have the corrected circles for the valve motion at the IV grades. These arcs are laid down for the neighborhood of the point of cut off only.

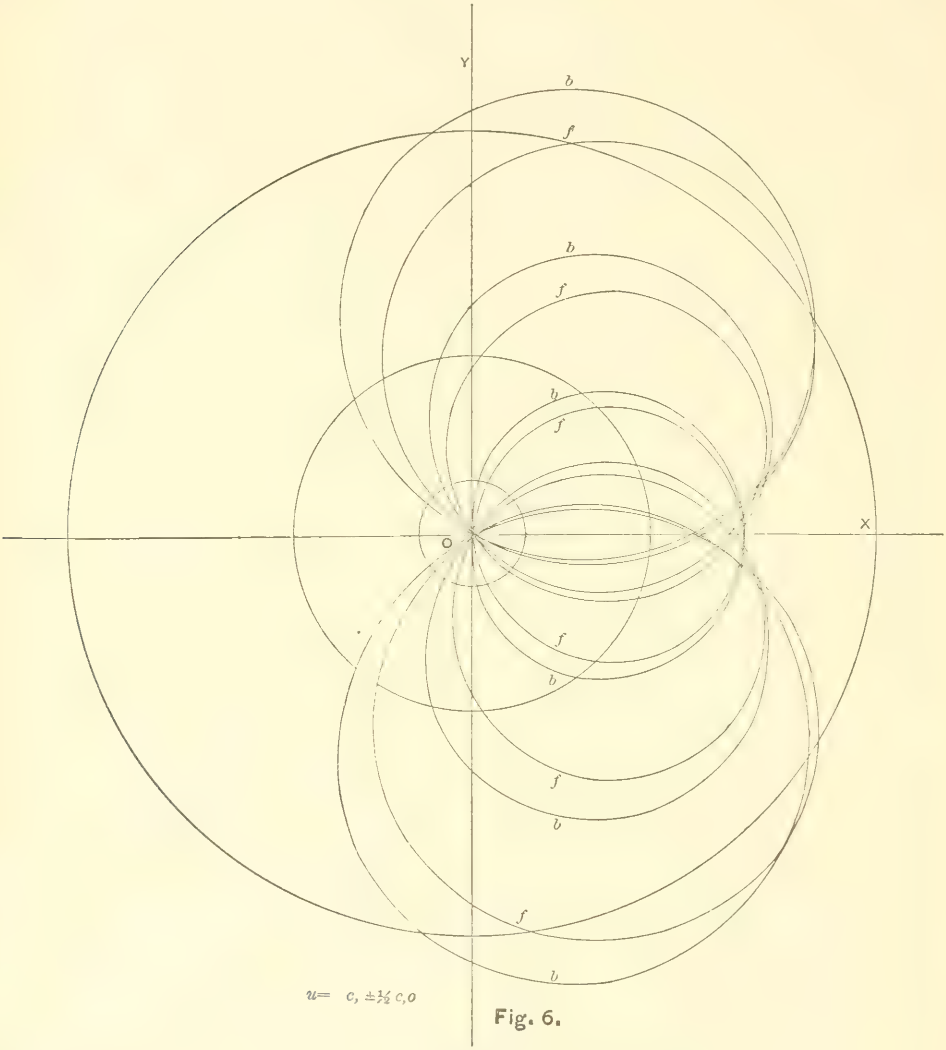


Fig. 6.

The distance PQ=the error which can be laid off both inside and outside the theoretical valve circle, as at *pf pb*. In the model $q=3$ inches, $\delta=30°$ and $c=5.9$ inches.

Therefore

$$\frac{c^2}{q\cos^2\delta}=15.47 \text{ inches.}$$

This most pernicious error can be avoided by use of the link, Fig. 2 *b*, although a larger eccentric is required, and, therefore, it is sometimes difficult to fit into confined spaces. Certainly it is of great importance to avoid so faulty a construction if it be possible.

Figs. 6 and 7 are diagrams automatically traced by the working model.

To avoid the errors due to suspension, the link block was clamped in the link for each grade, and the link, therefore, swung upon the rocker shaft arm.

To avoid the errors due to the "lost motion" the valve circles were traced twice by reversing the direction of the motion, and the mean between the two circles traced with pen and ink by hand, the difference was very slight, if any at all.

It will be seen that these actual valve curves verify with great accuracy the corrected valve circles, Fig. 4 for the fourth grade.

Similar corrections can be made for each grade of link if desired.

The letters *f* and *b* refer to the direction of motion of the piston head. Forward (*f*) meaning toward the crank shaft, and backward meaning away from the crank shaft. A rocker shaft intervened reversing the direction of motion of the valve.

When the form of link shown, Fig. 2*b*, is used, the increased eccentricity required will increase the "missing quantity" given by Prof. Zeuner, and it must, therefore, be guarded against, particularly in extreme cases.

Cases may occur when it will prove advantageous to attach the eccentric rods to the link at points nearer its center than the extreme limits of the travel of the link block, but special pains should be taken to place the center of the pin joint on the central arc of the link; this method of attachment, how-

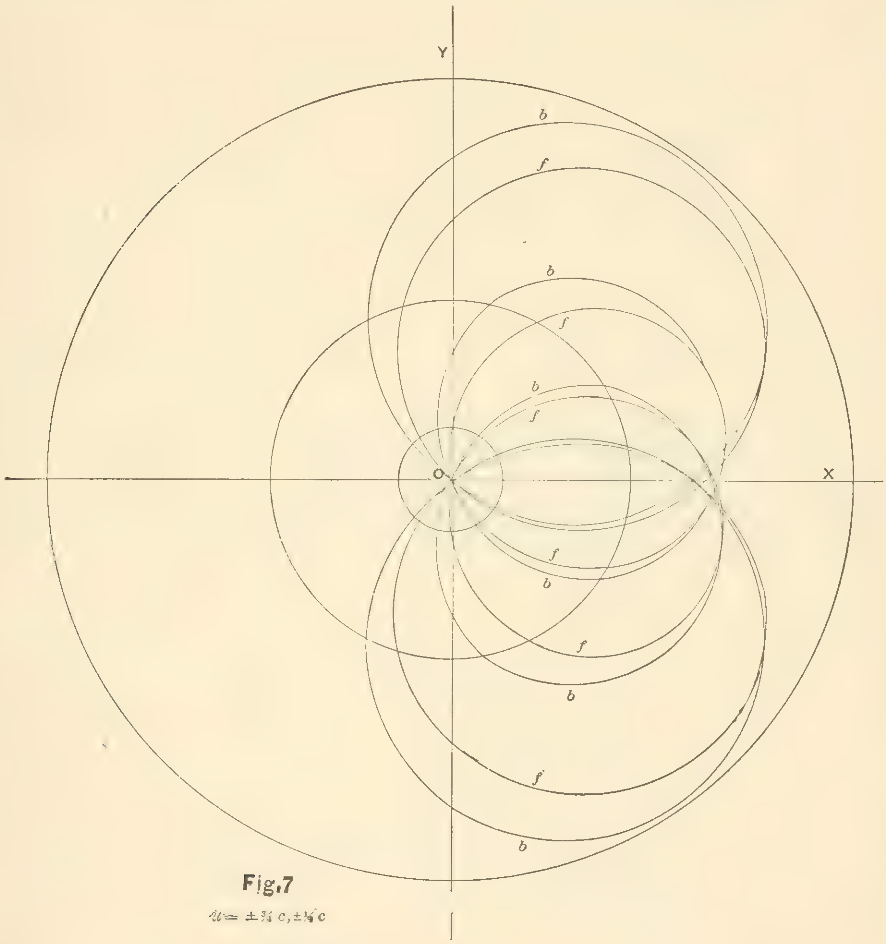


Fig. 7

$u = \pm \frac{3}{4} c, \pm \frac{1}{4} c$

ever, will result in increasing the slip of the link block.

V. Slip of the Link Block.

Zeuner gives two cases of the suspension of the link, by means of a hanger attached at the center of the chord of the link, and at the bottom of the link; in the first case the upper end of the hanger should theoretically move in an arc of a circle which has for a radius the length of the eccentric rod, and whose center is above the center line, a distance equal to the length of the hanger. The lower end of the hanger should be attached at the center of the link and on the central arc of the link, thus placing the origin of the arc of suspension at a horizontal distance equal to the length of the eccentric rod from the center of the crank shaft. Fig. 8 will render this clear. J_1 and not J should be the point of attachment of the hanger, and L not K_1 should be the center of the arc in which the upper end of the hanger E should move.

We can thus avoid increasing the slip by the quantity $\overline{JJ_1} \tan \alpha$ in one direction, and decreasing it by the same amount in the other direction.

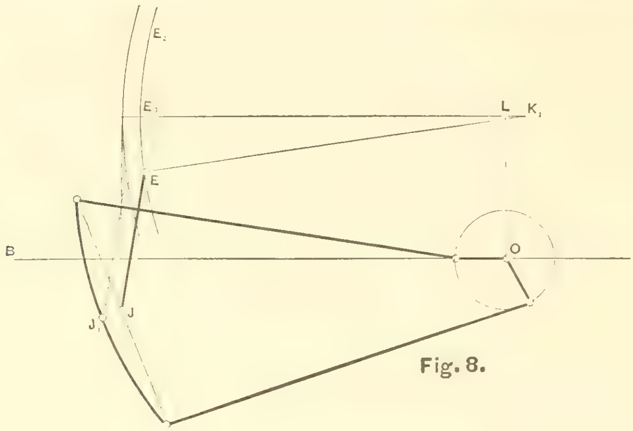


Fig. 8.

Fig. 9 shows the second method of suspension of the link, by a hanger attached to the bottom.

Both of these methods are fully explained by Zeuner, and the reader is referred to his work for further details.

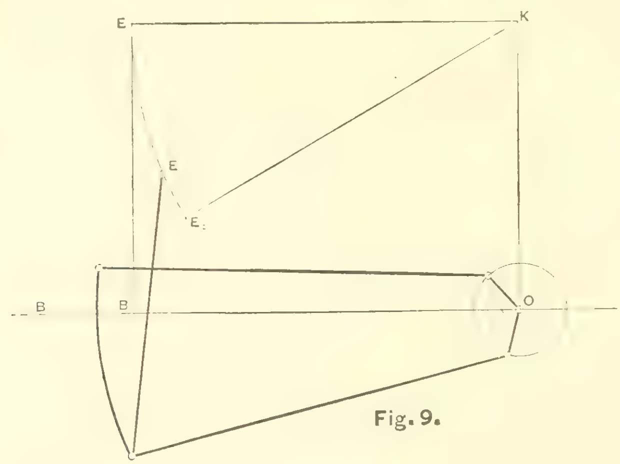


Fig. 9.

It will be perceived that the hanger is but a rude approximation to a parallel motion, used only because of its simplicity and lightness when the link block is forced to move to and fro in a straight line.

When the link block is attached to the end of a rocker-shaft arm, as is commonly the case for American locomotives, if the hanger is made the same length as the rocker-shaft arm there will be no slip when the link block coincides with the point of suspension, the slip for other positions of the link block will be due to the angular position of the link.

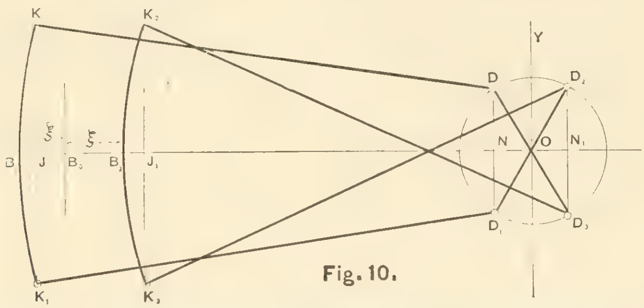


Fig. 10.

Assuming, when the block is forced to move in a straight line, that some method has been adopted to force the point of suspension of the link to move in an, at least very close approximation to a straight line, and, further, that when the link block moves in an arc of a circle of a given radius, that the

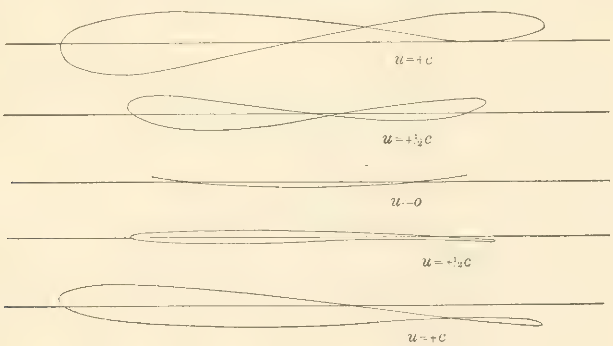


Fig. 11.

hanger is of the same length as this radius, we can consider the slip as due only to the angular position of the link.

Of course these conditions cannot always be fulfilled, but it is best to know what ought to be done, even if we cannot exactly do it.

Fig. 10 shows the two positions of the links KK_1 and K_2K_3, for which the slip is zero, and letting s equal the amount of slip for all other positions, if we suppose the hanger attached to the middle point of the link, and u the distance of the link block from that point, we will have

$$s=(\sec \alpha-1)u$$

or since the angle α is always very small

$$s=u(1-\cos \alpha)=u(1-\sqrt{1-\sin^2 \alpha})$$

and substituting for $\sin \alpha$ its value and expanding and neglecting all terms containing higher powers than the square of the circular functions, we have

$$s=\frac{ur^2}{2c^2}\cos^2\delta \sin^2 w$$

We thus see that the effect of the slip does not appear in the lead, but being a maximum for $w=90^\circ$ or 270°, will affect the points of cut off and exhaust closure.

Increasing the angular advance diminishes the slip, as also does increasing the length of the link. The tendency of the slip is to increase the travel of the valve by an amount V.

$$V=\frac{ur^3}{2c^3}\cos^3\delta \sin^3 w$$

This amount is very small for a well-proportioned valve gear, but it increases

directly as the distance u from the point of attachment of the hanger to the link.

When the link is suspended from the bottom, the value u must be replaced by $(c+u)$.

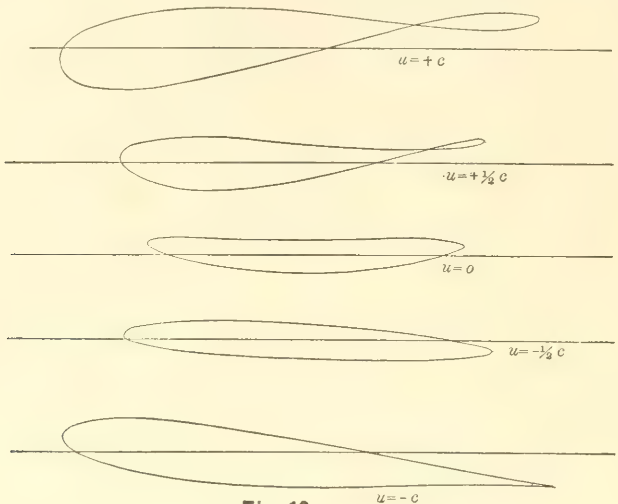


Fig. 12.

We thus see that for general usage at all points suspending the link at the middle is the best, while if one particular point is expected to be constantly

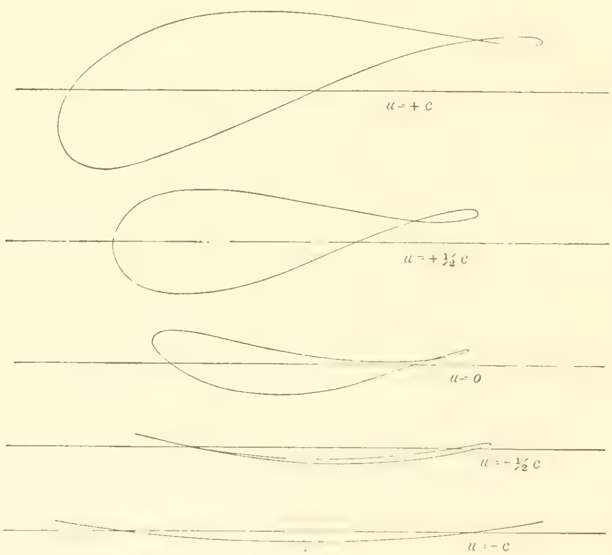


Fig. 13.

used, and the other points only exceptionally, it is best to attach the hanger to the link at that point.

If the tumbling-shaft arm cannot be made equal to the length of the eccentric rods, and for obvious reasons it rarely can be so proportioned, the center of the tumbling shaft must be so placed as to make an arc, struck with its arm as a radius, intersect the theoretical arc at the point or points of greatest usage.

From what has been said about the position of the arc of suspension, it will readily be perceived that its length on either side of the horizontal line $E_0 K_1$, Figs. 8 and 9, is determined by the point of attachment of the hanger to the link.

The link motion on which experiments were made with a view to testing the correctness of these results, had the following dimensions:

Length of eccentric rods $=l=18$ ins.
Radius of eccentricity $=r=1\frac{1}{4}$ "
Length of link $=2c=6$ "
Angular advance $=\delta=30°$
Open rods.

These results verify the above theory only in a qualitative way, as the upper end of the hanger was not always kept on the true arc of suspension.

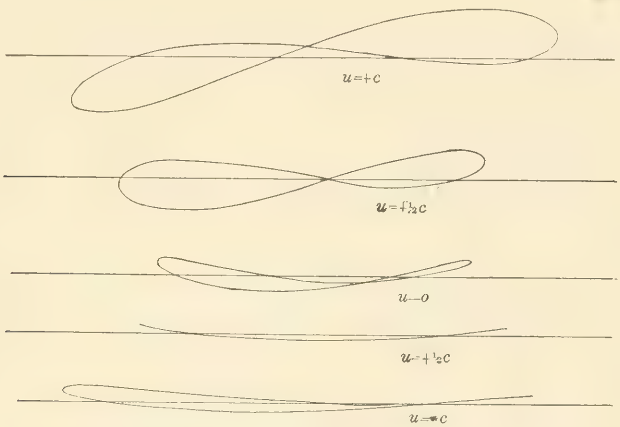


Fig. 14.

The link being suspended after the manner described a pencil was fixed in the link block, and the block successively fixed at different grades, the pencil being allowed to trace on a paper back of it, the curves of slip.

Case I. The link suspended at the center of its arc. Fig. 11 shows that the slip of the block increases both ways from its center, as had been predicted. The arc for $u=o$ is the standard with which the other curves must be compared.

Case II. The link being suspended at the center of its chord. Fig 12 is inserted merely for the purpose of showing an imperfect mode of suspension. All of the slip curves are bad, and at no point is there any cessation of the slip.

Case III. The link suspended at the bottom. Fig. 13 reveals the fact that the slip becomes very great for the upper end of the link, so great as to seriously affect the distribution of the steam. The lower half of the link only can be relied upon for accurate work.

Case IV. The link suspended half way between the bottom and center. Fig. 14 shows a better average result than any of the others, and is undoubtedly the best mode of hanging the link when the grade $u=-\frac{1}{2}c$ is to be generally used. Viewed from a practical point, slip is of great importance, being the cause of the wear upon links, which soon unfits them for accurate work. Great pains are taken to reduce this wear by case-hardening the links, or using steel in the place of wrought iron.

A proper mode of suspension is the most important point to be attained when the durability of the link motion is under consideration.

DESICCATING THE BLAST OF BLAST-FURNACES.

The process for desiccating the current of air supplied to blast-furnaces, patented by Mr. W. H. Fryer, of Coleford, Gloucester, having been referred to in a correspondence which recently appeared in our columns, and some interest having in consequence been awakened respecting it, we place before our readers

a description of the invention to which we add some observations upon the subject by Mr. Fryer. The majority of our readers need hardly be reminded that, in the ordinary method of manufacturing iron, the blast-furnace in which the iron ore is reduced is urged by a blast of atmospheric air. A blast of atmospheric air is also employed in the treating of iron by the Bessemer process for the production of steel, as well as in cupolas and refineries, in which iron is melted for casting and for refining. The blast employed is drawn direct from the atmosphere, and contains a greater or less amount of the vapor of water, varying with the hygrometrical condition of the atmosphere from time to time. This vapor undergoes decomposition in the furnace, causing an absorption and loss of heat, varying from time to time in proportion to the greater or less amount of vapor thus introduced in the blast. The hydrogen evolved by the decomposition referred to gives a porosity to the iron or steel under treatment, which is very injurious in castings.

Mr. Fryer's invention consists in the desiccation of the blast so as to prevent loss of heat, and thus to economize fuel and promote rapidity of fusion and a regular working of the furnace, and also to prevent to some extent the porosity produced in the iron or steel made with air containing vapor of water. In practice, the air to be forced into the furnace, or Bessemer converter, is passed over sulphuric acid or chloride of calcium, so as to deprive the air of the vapor of water contained in it. The desiccating material is disposed in a chamber through which the air is passed, the particular arrangement depending upon the nature of the material employed (whether solid or liquid) and its desiccating and other properties, the essential conditions of the arrangement being that the desiccating material shall expose a large surface to the air, and that the capacity of the chamber shall be such that the air will travel through it at a sufficiently slow rate to insure the thorough action of the desiccating material upon it.

Such, briefly, are the principles of Mr. Fryer's invention, the description of which may be appropriately supplemented by the following considerations, on the application of desiccated air to the blast-furnace, from the pen of the inventor:

The total quantity of heat evolved by the combustion of the carbon of the fuel, added to that introduced by the preliminary heating of the blast, is already more than sufficient, after deducting the quantity absorbed as latent heat in the zone of fusion, to heat the iron and slag-forming materials up to their melting points; a large surplus escaping thereafter from the furnace top.

The heat so produced in the hearth is practically divisible into two portions or quantities: (1.) The sum of the heat at and below the temperature requisite to fuse the materials in question. (2.) The sum of the heat above such temperature. The former passes without absorption as latent heat, and therefore without melting effect, through the zone of fusion; becoming subsequently only partially absorbed in raising the said materials to the melting point in the upper part of the furnace. The latter is alone absorbed by the previously heated materials and effects their fusion. As the former is already in excess, the rapidity of the fusion, and consequently the "make" of the furnace is determined primarily by the latter, and increases in direct ratio therewith.

The practical bearing of this will, perhaps, be more clearly seen when regard is had to the narrow limits between the ordinary temperature in the furnace hearth and the temperature at which fusion commences. Increase of the furnace make must be sought by adding to this excess of the actual over the absolutely required temperature. The desiccation of the blast effects such addition, or what is the same thing, prevents the absorption of the heat caused by the dissociation of the aqueous vapor in the hearth of the furnace; heat which, as Mr. Lowthian Bell remarks, "is absorbed where it is most wanted" (*i. e.*, in the hearth) "and evolved where its presence is a questionable benefit" (*i. e.*, in the upper part of the furnace).* In order to compare the additional heat thus thrown into the hearth with the available excess previously existing there, take, for example, the following case referred to by Mr. Bell†: Furnace 11,500

*Journal of Iron and Steel Institute, No. 1, 1871; p. 198.
†Journal of Iron and Steel Institute, No. 2, 1871; p. 279.

cubic feet capacity; making No. 3 pig iron from calcined Cleveland ironstone, and producing 30.4 cwt. slag per 20 cwt. pig iron. The heat absorbed by the dissociation of the H_2O in blast (taken at an average of 0.74 cwt. per ton of iron) is estimated by Mr. Bell at 2720 units centigrade per 20 units of pig iron made.

In estimating the total heat absorbed by the materials fused, Mr. Bell does not distinguish between the heat absorbed in melting, as latent heat, and the heat absorbed in the upper portion of the furnace in raising the materials to the melting point. In order to arrive at the former, recourse is had to the data adopted by M. Schintz in his "Researches on the Blast Furnace," and accordingly the heat absorbed in actually melting is as follows:

Iron, 20 units $\times$ 175 = 3500
Slag, 30.4 " $\times$ 60 = 1824

Total latent heat = 5324 units.

whilst (as above shown) the heat absorbed by the decomposition of the aqueous vapor in the blast amounts to 2720 units, or 51 per cent. as much heat as the total amount actually expended in melting. Compare this with actual results. By observations extended over a period of five years the late Mr. Truran, at Dowlais, found that, under otherwise similar conditions, the excess only of the average percentage of moisture in the air in autumn over winter effected, in the ballast iron furnace, a diminution in the make of iron of 13 per cent. in quantity, besides producing an inferior quality of metal.*

According to Mahlmann† the mean temperature at Cheltenham (the nearest observed station to Dowlais), is recorded as follows: Autumn, 10.1 C.; winter, 3.8 C.; the weight of water required to saturate 1 cubic meter of air at these temperatures being 10.63 and 7.22 grammes, respectively. The table on p. 92 of the work above referred to gives the mean relative humidity at Halle as follows: Autumn, 79; winter, 83.70 per cent. of the amount required for saturation; whence the mean actual weight of moisture present is as follows: Autumn, 8.3977; winter, 6.0431 grammes per cubic meter. The mean weight of moisture present, therefore, in the air in winter is nearly 3-4ths of the weight present in autumn; and as the removal of the 1-4th (excess in autumn over winter) effected an addition to the furnace make of 13 per cent., the further increase due to the removal of the other 3-4ths would be $13 \times 3 = 39$ per cent.; making the total increase due to the complete desiccation of the blast $13 + 39 = 52$ per cent.

That the whole of the 2720 heat-units absorbed by the dissociation of the H_2O would be so much clear gain, is, of course, not strictly accurate; since the oxygen thus liberated would supply the place of an equal weight of atmospheric oxygen, and save the specific heat absorbed by its proportionate weight of nitrogen (in the case in point) 329 heat units; leaving, net, 2391 units. In smaller furnaces, however, requiring more coke, and, consequently, more blast, per ton, the heat absorbed by the dissociation of the H_2O would be proportionately greater.

The cost of desiccating the blast is practically limited to the cost of evaporating and re-fusing the chloride of calcium; or of re-concentrating the sulphuric acid, as the case may be; adding, of course, a small margin for the labor of charging, and for occasional repairs, and renewals for waste. That cost is, practically, the value of the fuel employed, or, in other words, the cost of the heat units absorbed in physically expelling the absorbed water from the desiccating material. But without at present entering minutely into this, or considering, on the other hand, the saving of interest and working expenses involved in an increased furnace make, it is self-evident that the heat units thus expended in simply expelling the water absorbed by the desiccating material, will be incomparably less than the heat units absorbed by the chemical decomposition of the same water, if allowed to pass into the hearth of a blast furnace. The saving of fuel should, of course, be in proportion. The various other advantages of an increased furnace make, and of at the same time avoiding the irregularities caused by daily variations in the hygrometrical condition of the blast,

* Iron Manufactures of Great Britain; 3rd edition, 1865; p. 94 *et seq.*

† Kämtz's Meteorology, translated by Walker; p. 181–2.

with their disturbing effect on the working of the furnace, will be well understood by all who have had experience in the matter. There still remain for notice some considerations on the application of the process for the special production of alloys of iron and manganese in the blast furnace. In this case the reduction to the metallic state of the oxides of the latter metal contained in the ore is obviously a primary necessity. But the heat absorbed in dissociating a given weight of manganese from its combined oxygen is considerably greater than the amount absorbed in dissociating an equal weight of iron from its combined oxygen. Manganese also requires for its fusion a much higher temperature than iron. Hence in the normal working of an ordinary blast furnace, however much oxide of manganese be introduced with the ore, it remains unreduced, combines, as protoxide, with the silica of the charge, and passes off in the slag.

It has also been maintained that the reduction of manganese is effected solely by solid carbon; that, unlike iron, its reduction is effected, not by the carbonic oxide in the upper portion of the furnace, but, at a later stage, by the unconsumed carbon in the lower portion. For this reason, also, a higher temperature is requisite; because the higher the temperature the more rapid the fusion of the lower layers of the charges, and, consequently, the more rapid the descent of the upper layers, thus adding to the height of the column of solid carbon in the hearth, and so prolonging the intimate contact of the unreduced oxide therewith, and promoting the reduction of the manganese and its consequent solution in the molten iron.*

The conditions, therefore, to be attained in the manufacture in the blast furnace of alloys of iron and manganese are: (1) A very high temperature in the hearth (to effect the reduction and fusion of the manganese); and (2) A highly basic slag (to prevent combination of the yet unreduced oxide of manganese with silica). But the more basic the slag, the more infusible it is; requiring, in such case, a proportionately higher temperature also; whilst from the fact of the greater amount of heat absorbed in the reduction of manganese, it is (as Prof. Akerman has pointed out) even more difficult to attain a given high temperature when reducing manganese, than when simply reducing iron. Such, in fact, is the difficulty and cost of maintaining the high temperature necessary for the reduction of manganese, that the consumption of coke in the manufacture of the best ferro-manganese is about four times more per ton than in the manufacture of ordinary pig iron, and the daily furnace yield about four times less; one-third or so of the total amount of manganese nevertheless passing off unreduced.*

Under such conditions, the importance of desiccating the blast, and thus avoiding the loss of temperature in the hearth, caused by the dissociation of its aqueous elements, is apparent. The adoption of this process would, at the same time, prevent the occlusion of the otherwise dissociated hydrogen in the resulting metal; thereby adding to its value for the production of steel, free from the hydrogen cells formed whilst cooling, and which constitute the so-called "blown holes" in ordinary castings.†

* Schintz on "Blast Furnace," pp. 3, 141.

*Article by Prof. Akerman, in *Iron* of January 30, 1880.

† Dr. F. C. G. Müller "Ueberdie Gasausscheidungen in Bessemergüssen."

The total extent of the ground occupied by the Brussels Exhibition is 300,000 square meters, and the area covered by the palace 70,000. The number of exhibitors is 7,000, or more than one for each 1,000 inhabitants in a population of about 6,000,000. Two of the pavilions are occupied by the two principal telephonic companies, who are competing at Brussels, Antwerp, and Verviers, where rival central offices have been built, and are besieged by a crowd of experimenters. The number of tickets sold at the gate is about 10,000 a day, which is considered a success. It was attempted to establish a captive balloon on the model of the large Giffard captive balloon on a reduced scale, the rope being only 300 meters long instead of 500, and the volume 8,400 cubic meters in stead of 25,000. But in spite of this dimunition the balloon refused to go up, the hydrogen having been mixed with a large quantity of common air.

THE RELATIVE AMOUNTS OF WORK PERFORMED IN PROPELLING BOATS BY PADDLE-WHEEL AND BY CABLE.

By J. B. JOHNSON, Assistant Engineer of U. S. Lake Survey.

The following discussion is an attempt at the solution of two problems, viz:

1. *What are the relative amounts of work performed in propelling a boat by a reaction from the water itself, and by drawing upon a fixed cable, for any rate of current, and for any speed?*

2. *What rate of speed will employ the minimum amount of work for a given distance by these two methods, for any velocity of current?*

It will be found that the second problem is a corollary to the first.

These problems have not only great theoretical and practical interest in themselves, but at this time derive a peculiar interest from the pending discussion concerning these two methods of navigation which are now in use on the Erie canal.

By *work* is meant force into the distance through which the force is made to act. The work required to raise 100 lbs., 1 ft., or 1 lb., 100 ft., is said to be 100 foot-pounds. Here the unit of work is 1 pound raised 1 foot, or a foot-pound. *In the following discussion, the unit of work is the amount required to draw a given boat by cable in still water one mile, at the rate of one mile per hour.* The work required to do this will be called 1. To draw the same boat two miles at the same rate, would employ twice the amount of work, or work=2. Here the force has remained the same, since the rate is the same, but the distance through which it acted has changed. To draw the same boat 1 mile at twice the rate, or at the rate of 2 miles per hour, would require four times the amount of work, or work=4. Here the distance has remained the same, but the force has changed, since the rate is twice as great.

It is a recognized principle in dynamics, that when a body moves through a constant fluid medium, the resistance it encounters is directly as the square of its velocity.*

The work done in propelling a boat at a uniform speed is simply overcoming the resistance to its motion. This resistance varies as the square of its velocity through the water. Therefore, the work done, or fuel consumed, in propelling a boat *over a given space*, varies as the square of the velocity of the boat. If, however, we are treating of the amount of work done *in a unit of time*, or horse power, we find it increases as the *cube* of the velocity. For the force increases as the square of the velocity, and the distance traversed in a unit of time increases as the first power of the velocity, and hence their product, or the work done in a unit of time, increases as the cube of the velocity.

When a boat is drawn by cable, the *force* is the tension on the cable, and the *distance* through which it acts is the distance the boat moves *with reference to the cable.*

When a boat is propelled by a reaction of the water, the *force* is the same as though the boat were drawn at the same rate by cable, and the *distance* through which it acts is the distance the boat moves *with reference to the water from which the force reacts.* Thus when a boat is propelled through the water by paddle wheel or by screw, the wheel imparts to the water a motion, and this moving water reacts against the wheel, and this reaction propels the boat. Therefore the distance through which the force acts, in this case, is the distance the boat moves with reference to the moving water which reacts against the wheel. This backward motion imparted to the water is called the *slip*. The slip is about 25 per cent. of the motion

* See Price's Calculus, vol. III., sec. 267, and Morin's Mechanics, sec. 299 *et seq.* In the former it is derived theoretically, in the latter empirically, from experiments on boats drawn in water.

of the wheel in a well-proportioned boat in large channels, but sometimes becomes as much as 50 or 60 per cent. in confined channels like canals.

MOTION UP STREAM.

If two similar boats, one drawn by a cable and the other propelled by a wheel, move up stream against a constant current at the same rate, the forces required to propel them will be equal. The distance through which the force acts, for the boat drawn by cable, will be the distance the boat actually moves up stream, the same as before. With the self-propelling boat, the distance through which the force acts is the distance moved up stream + distance the current has run in that time + the slip.

This may perhaps be made clearer by an illustration:

1. If a man, weighing 150 pounds, climbs a stairway 12 feet high, he raises his weight through 12 feet, and performs 1800 foot-pounds of work.

2. If he raises his body the same distance by climbing up a rope, he again performs 1800 foot-pounds of work.

3. If the rope has a downward motion, such, that while he is climbing it moves down 6 feet, he has to climb 18 feet, and performs 2700 foot-pounds of work.

4. If the rope moves down 6 feet, and he also slips back 25 per cent. of all he climbs, then in order to raise his body through the given 12 feet, he must climb 12 feet + 6 feet + 6 feet = 24 feet, and must perform 3600 foot-pounds of work.

The first case corresponds to the boat drawn by the fixed cable, the fourth to the self-propelling boat.

MOTION DOWN STREAM.

If two similar boats move at the same rate down stream with a constant current, the forces required to propel them are again equal. The distance through which the force acts, for the cable boat, is the distance it travels, the same as up stream. The distance through which the force acts, for the self-propelling boat, is now the distance the boat travels—distance current has run in that time + the slip.

From this we conclude that the work done by the self-propelling boat is always greater than that done by the boat drawn by cable, when moving in still water and up stream; and that it is greater when moving down stream when the slip is more than the current; when the slip is less than the current, the cable boat does more work than the self-propeller.

The exact relations of the amount of work performed by the two systems are given by the following

FORMULÆ:

Let f = force required to draw given boat by cable one mile per hour in still water.
s = distance in miles.
v = velocity of boat through the water in miles per hour.
r = rate of current in miles per hour.
u = " " speed " " " "
t = time in hours.
Wc = work performed, or fuel consumed, by cable boat.
Wp = work performed, or fuel consumed, by screw or paddle boat.
a = 1 + percentage slip is of boat's motion (when slip = 25 per cent. $a=\frac{4}{3}$).*

Then

I. IN STILL WATER.

(*a*) *For a given distance.*

$$Wc=fsv^2 \quad . \quad . \quad . \quad . \quad (1)$$
$$Wp=afsv^2 \quad . \quad . \quad . \quad (2)$$

(*b*) *For a given time.*

$$Wc=ftv^3 \quad . \quad . \quad . \quad . \quad (3)$$
$$Wp=aftv^3 \quad . \quad . \quad . \quad . \quad (4)$$

II. UP STREAM, AGAINST A CURRENT r.

(*a*) *For a given distance.*

$$Wc=fsv^2=fs(u+r)^2 \quad . \quad . \quad . \quad . \quad (5)$$
$$Wp=af(s+rt)v^2$$

But

$$t=\frac{s}{v-r}$$

therefore

$$Wp=afs\,(1+\frac{r}{v-r}\,v^2 \quad . \quad . \quad . \quad (6)$$

$$=afs\,\frac{v^3}{v-r}=afs\,\frac{(u+r)^3}{u} \quad . \quad . \quad (7)$$

(*b*) *For a given time.*

$$Wc=ftv^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

* Since slip is wheel's motion—boat's motion, if the slip is one-quarter of the wheel's motion, it is one-third of the boat's motion.

$$Wp = aft\left(1+\frac{r}{v-r}\right)v^3 = aft\frac{v^4}{v-r} \quad . \; . \; . \; (9)$$

III. DOWN STREAM WITH A CURRENT r.

(*a*) *For a given distance.*

$$Wc = fsv^2 = fs(u-r)^2 \quad . \; . \; . \; (10)$$

$$Wp = af(s-rt)v^2$$

But

$$t = \frac{s}{r+v}$$

therefore

$$Wp = afs\left(1-\frac{r}{v+r}\right)v^2$$

$$= afs\frac{v^3}{v+r} = afs\frac{(u-r)^3}{u} \quad . \; . \; . \; (11)$$

(*b*) *For a given time.*

$$Wc = ftv^3 \quad . \; . \; . \; . \; . \; (12)$$

$$Wp = aft\left(1-\frac{r}{v+r}\right)v^3$$

$$= aft\frac{v^4}{v+r} \quad . \; . \; . \; . \; (13)$$

Equation (7) when solved for minimum becomes

$$3v^2(v-r) - v^3 = o$$

$$2v - 3r = o$$

whence $\quad v = \frac{3}{2}r \quad . \; . \; . \; (14)$

Thus we see, from eq. (14), that the most economical rate for a self-propelling boat to move up stream is at a speed through the water equal to one and one-half times the rate of the current, or it moves up stream at one-half the rate of the current. This is also shown by the curves.

RESULTS.

If we let the unit of work (or of fuel) be that required to draw a given boat 1 mile by cable in still water at the rate of 1 mile per hour, and assuming a slip of 25 per cent. for paddle or screw-boats, whence $a = \frac{4}{3}$, eqs. (5), (7), (10) and (11) give the following tables of work by substituting values for u and r.

It will be seen that these tables are not intended to give absolute values for work, or consumption of fuel, for any given case, but only relative values for the same boat by the two methods.

It might seem unnecessary to give a table of work done by the cable-drawn boat, since it is always equal to fsv^2, but for the purposes of ready comparison it is given below.

It may also be remarked that the work required to draw a boat by pulling on a fixed cable is the same as that employed in drawing same boat at same rate by horses on the tow-path; so that all the following tables and curves of work for cable apply equally to a boat drawn by horses. This equality, however, is only in the amount of work performed. Since the character of the power is different; an equality of work does not imply an equality of cost, which is implied in the case of the two steamboats.

The curves of work given below are plotted from these tables of coördinates. Each column gives a separate curve. The four curves in Plate I are the plots of columns 1 and 5 of Tables I and III. The four in Plate II are from columns 2 and 5 of Tables II and IV.

In these curves the work is plotted for ordinates, and the speed of the boat for abscissas. The speed is its rate through the water, plus or minus the rate of the current ($u = v \pm r$).

WORK IN STILL WATER.

Curves 1 and 2, Plate I, show the relative amounts of work required for the cable and paddle-wheel boats, respectively, in still water. These curves are both parabolas, the ordinates of 2 being always $\frac{4}{3}$ of those of 1. This difference is simply the slip of the paddle or screw-wheel boat.

Therefore, in still water, if the slip is 25 *per cent., a boat may be drawn at any given rate by cable for* $\frac{3}{4}$ *of the expenditure of fuel that would be required for a self-propelling boat. If the slip is* 50 *per cent., it would require but half the fuel.*

WORK IN GOING UP STREAM.

Curves 3 and 4, Plate I, show the relative amounts of work performed, or fuel consumed, by a cable-drawn and a self-propelling boat respectively, when moving up stream against a current of four miles per hour.

Curve 3, work by cable, is the same parabola as curve 1, but its axis is now moved 4 units to the left.

Curve 4, work for self-propeller, has a point of minimum at $u=2$, which is in accordance with eq. (14), and becomes tangent to the axis of ordinates at $+\infty$. It is therefore an asymptote to that axis.

Tables of Work Performed, or Fuel Consumed in Going 1 Mile when Boat is Drawn by Cable for Different Rates of Speed and of Current.

Table I.—Up Stream. Eq. (5) $Wc = fsv^2 = fs\,(u+r)^2$.

Rate of Speed in mi. pr. hr. $=u$.	Still Water. $r=o$.	$r=$ 1 mi. pr. hr.	$r=$ 2 mi. pr. hr.	$r=$ 3 mi. pr. hr.	$r=$ 4 mi. pr. hr.	$r=$ 5 mi. pr. hr.	$r=$ 6 mi. pr. hr.
0	0	1	4	9	16	25	36
1	1	4	9	16	25	36	49
2	4	9	16	25	36	49	64
3	9	16	25	36	49	64	81
4	16	25	36	49	64	81	100
5	25	36	49	64	81	100	121
6	36	49	64	81	100	121	144
7	49	54	81	100	121	144	169
8	64	81	100	121	144	169	196
9	81	100	121	144	169	196	225
10	100	121	144	169	196	225	256
11	121	144	169	196	225	256	289
12	144	169	196	225	256	289	324
13	169	196	225	256	289	324	
14	196	225	256	289	324		
15	225	256	289	324			
16	256	289	324				
17	289	324					
18	324						

Table II.—Down Stream. Eq. (10) $Wc = fsv^2 = fs\,(u-r)^2$.

Rate of Speed in mi. pr. hr. $=u$.	Still Water $r=o$.	$r=$ 1 mi. pr. hr.	$r=$ 2 mi. pr. hr.	$r=$ 3 mi. pr. hr.	$r=$ 4 mi. pr. hr.	$r=$ 5 mi. pr. hr.	$r=$ 6 mi. pr. hr.
0	0	—1	—4	—9	—16	—25	—36
1	1	0	—1	—4	— 9	—16	—25
2	4	1	0	—1	— 4	— 9	—16
3	9	4	1	0	— 1	— 4	— 9
4	16	9	4	1	0	— 1	— 4
5	25	16	9	4	1	0	— 1
6	36	25	16	9	4	1	0
7	49	36	25	16	9	4	1
8	64	49	36	25	16	9	4
9	81	64	49	36	25	16	9
10	100	81	64	49	36	25	16
11	121	100	81	64	49	36	25
12	144	121	100	81	64	49	36
13	169	144	121	100	81	64	49
14	196	169	144	121	100	81	64
15	225	196	169	144	121	100	81
16	256	225	196	169	144	121	100
17	289	256	225	196	169	144	121
18	324	289	256	225	196	169	144

TABLES OF WORK PERFORMED, OR FUEL CONSUMED, IN GOING 1 MILE WHEN BOAT IS PROPELLED BY WHEEL, FOR DIFFERENT RATES OF SPEED AND OF CURRENT.

TABLE III.—UP STREAM. Eq. (7) $Wp = \frac{4}{3} fs\,(u+r)^3$.

Rates of Speed in mi. pr. hr. $=u$.	Still Water. $r=o$.	$r=1$ mi. pr. hr.	$r=2$ mi. pr. hr.	$r=3$ mi. pr. hr.	$r=4$ mi. pr. hr.	$r=5$ mi. pr. hr.	$r=6$ mi. pr. hr.
0	0	∞	∞	∞	∞	∞	∞
1	1.3	11	36	85	167	288	457
2	5.3	18	43	83	144	229	341
3	12.0	28	56	96	152	228	324
4	21 3	42	72	114	171	243	333
5	33.3	58	92	136	194	266	355
6	48.0	76	114	162	222	296	384
7	65.3	98	139	190	254	329	419
8	85.3	122	167	222	288	366	457
9	108.0	148	197	256	326	406	500
10	133.3	178	230	293	366	450	546
11	161.3	210	266	333	409	496	596
12	192.0	244	305	375	455	546	648
13	225.3	282	346	420	504	598	
14	261.3	321	390	468	555		
15	300.0	364	437	518			
16	341.3	409	486				
17	385.3	457					
18	432.0						

TABLE IV.—DOWN STREAM. Eq. (11) $Wp = \frac{4}{3} fs \frac{(u-r)^3}{u}$.

Rate of Speed in mi. pr. hr. $=u$.	Still Water $r=o$.	$r=1$ mi. pr. hr.	$r=2$ mi. pr. hr.	$r=3$ mi. pr. hr.	$r=4$ mi. pr. hr.	$r=5$ mi. pr. hr.	$r=6$ mi. pr. hr.
0	0	—∞	— ∞	— ∞	— ∞	— ∞	— ∞
1	1.3	0	—1.3	—10.7	—36.0	—85.3	—166.7
2	5.3	0.7	0	— 0.7	— 5.3	—18.0	— 42.6
3	12.0	3.6	0.4	0	— 0.4	— 3.6	— 12.0
4	21.3	9.0	2.7	0.3	0	— 0.3	— 2.7
5	33.3	17.1	7.2	2.1	0.3	0	— 0.3
6	48.0	27.8	14.2	6.0	1.8	0.2	0
7	65.3	41.1	22.4	12.2	5.1	1.5	0.2
8	85.3	57.2	36.0	20.8	10.7	4.5	1.3
9	108.0	75.9	50.8	32.0	18.5	9.5	4.0
10	133.3	97.2	68.3	45.7	28.8	16.7	8.6
11	161.3	121.2	88.4	62.1	41.6	26.2	15.2
12	192.0	147.9	111.1	81.0	56.9	38.1	24.0
13	225.3	177.2	136.5	102.6	74.8	52.5	35.2
14	261 3	209.2	164.6	126.8	95.2	69.4	48.8
15	300.0	243.9	195.3	153.6	118.3	88.8	64.8
16	341.3	281.2	228.7	183.1	144.0	110.9	83.5
17	385.3	324.8	264.7	215.2	172.3	135.5	104.4
18	432.0	363.9	303.4	250.0	203.3	162.7	128.0

By an inspection of these curves, we may derive the following laws:

1. *The work expended by drawing a boat a given distance up stream by cable is a minimum at a zero speed, and increases on the line of a parabola to* $+\infty$ *for an infinite rate of speed.*

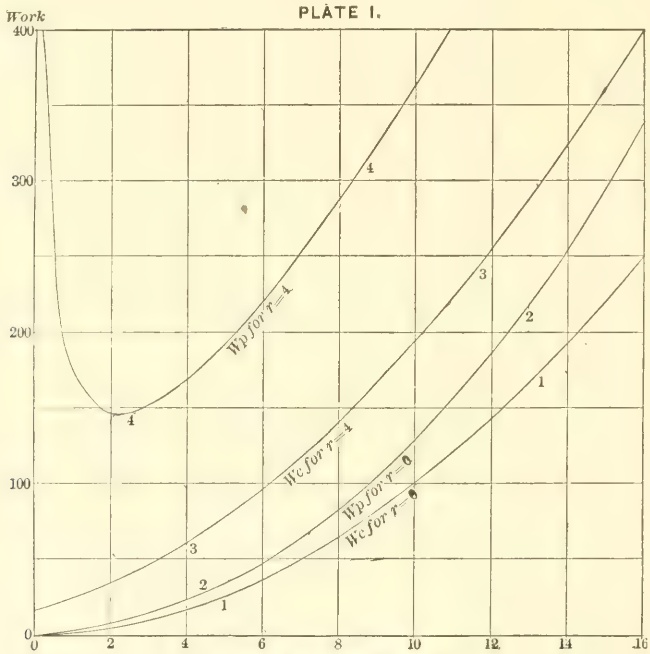
2. *The work expended in propelling a boat a given distance up stream by paddles or screw-wheel, is* $+\infty$ *for a zero speed, decreases to a minimum for a speed equal to* $\frac{1}{2}$ *rate of current, and then increases to* $+\infty$ *for an infinite speed.*

system increases rapidly with an increase of current. (The reader might construct curves from the other columns in Tables I and III, and see this increase more clearly).

ON THE ERIE CANAL.

The last New York State Engineer's Report shows that a screw propeller on the Erie Canal has a slip of about 40 per cent.; a in the above formulæ then becomes $\frac{5}{3}$ instead of $\frac{4}{3}$ as was used in the Tables. He also shows that the rate of current is about one-half a mile per hour. Substituting these values for a

PLATE I.



The relative amounts of work required by the two methods cannot be given in general, except that it is always less for the cable boat when navigating in still water or up stream. In still water the advantage over the self-propeller is 25 to 50 per cent. (the amount of the slip). From curves 3 and 4, Plate I (column 5, Tables I and III) we may see that, against a 4 mile current, for a speed of 2 miles per hour, the ratio of work by the two methods is as 36 to 144; for a speed of 4 miles, 64 to 171; for speed of 6 miles, 100 to 222; for speed of 8 miles, 144 to 288, &c. It is apparent that the advantage of the cable

and r in eqs. (5) (7) (10) and (11) we have the relative work performed by the two methods of screw-propelling and cable-towing on the Erie Canal in going

AGAINST THE CURRENT.

Speed in miles per hour.	Work by Cable or Horses.	Work by Screw Propeller.
1	2	4
2	6	12
3	12	24
4	20	38
5	30	55
6	42	76

WITH THE CURRENT.

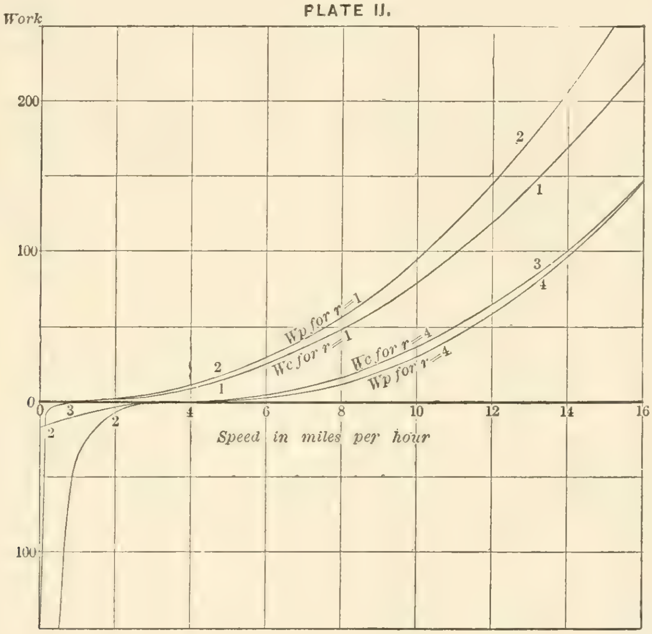
Speed in miles per hour.	Work by Cable or Horses.	Work by Screw Propeller.
2	2	3
3	6	8
4	12	18
5	20	30
6	30	46

We thus see that on the Erie Canal, in going against a half-mile current, the screw propeller expends about twice the before. Thus when time is not considered, but only the economy of fuel or of muscular energy, the most economical rate is as above stated. The same law obtains in the case of one vessel pursuing another. The pursuing vessel will overtake the forward one with the smallest expenditure of fuel when its rate is $1\frac{1}{2}$ times that of the forward vessel.

WORK IN GOING DOWN STREAM.

The curves in Plate II show the relative work by the two methods in going down stream. Curves 1 and 3 give the

PLATE II.



work, and in going with the current about $\frac{2}{3}$ the work required to draw the same boat at same rate by cable or by horses. The question of economy, as between the cable and horses, is a practical one, with which we here have nothing to do.

THE MOST ECONOMICAL RATE UP STREAM.

The fact, that the work required for a self-propelling boat to accomplish a given distance against current, tide, or drifting wind, is a minimum when the speed is one-half the rate of the opposing current, tide, or drift, is a very important one. It has, however, been observed work by the cable system for rates of current of 1 and 4 miles respectively, and curves 2 and 4 for a self-propelling boat at the same rates. It will be seen that for a current of 1 mile per hour the cable boat always has the advantage, the work being always less. For a 4 mile current, the work is greater by the cable system up to a speed of 16 miles per hour. If all the columns in Tables II and IV were plotted, it would be seen that with a current of less than 2 miles per hour, the cable system still requires less work even in going down stream.

The parts of these curves, continued below the axis of abscissas, give the

amount of negative work done by the boat when its speed down stream is less than that of the current. In this case, to reach a given distance down stream at a zero speed, the negative work by a self-propelling boat would be $-\infty$. The curves for the self-propelling boat, 1 and 4, therefore, are asymptotes to the axis of ordinates below the origin. Curves 1 and 3 are parabolas both above and below the axis.

HORSE POWER OF ENGINES.

By taking the equations of *work in a given time*, we would find the relative-sized engines required by the two methods for giving rates of speed and of current.

Thus, if we assume, for the sake of having a convenient unit, that it requires an engine of 1 horse-power to draw a given boat by cable at the rate of 1 mile per hour in still water, we obtain from eqs. (8) and (9) by making $r=\frac{1}{2}$ and $a=\frac{5}{3}$, for navigation on the Erie Canal.

AGAINST THE CURRENT.

Speed in miles per hour.	No. H. P. of Engine for Cable Boat.	No H.P. of Engine of Screw-wheel Boat.
1	3	8
2	16	33
3	43	83
4	91	171
5	166	304

It may be remarked, that in this discussion, no account has been taken of the additional work employed in handling the cable, but this would certainly be small. It has also been assumed that the cable-drawn boat was not one of a line of tows, but that it grappled the cable itself.

The work, in every case, has been computed for a given velocity, after such velocity has been acquired. The overcoming of the inertia of the boat in starting it has not been considered.

FUEL-GAS, AND THE STRONG WATER-GAS SYSTEM.

By Dr. HENRY WURTZ, New York City.

From Transactions of the American Institute of Mining Engineers.

HERACLITUS, a sage of antiquity, called the dark philosopher, who refused a throne, preferring a hermit's cell, propounded, twenty-four centuries since, the maxim:

War (or strife) engenders all things.

This, though probably intended by Heraclitus to apply especially to the internal forces of nature, is often said, with equal reason, of the affairs of men. Controversial strife, whether fortunately or unfortunately, is a crucible through which all new discoveries in science, and all technical applications of science must pass—a test which they must all endure before they can become so vitalized as to germinate, so to speak, take root in the human mind, grow up, and overspread the earth. The greater the number and the power of the elements arrayed against such a growth, and of the influences hostile thereto, the greater should be the inherent vitality of the germ, the more strenuous, skillful, and persistent its cultivators and upholders.

During the decade last past we have had, in spite of the severe stringency of the times, an active growth of this kind in progress, whose prospective importance it would now be difficult to overrate. This is the movement which has for its motive the idea that, generally speaking, *fuel should be gaseous in form*, and which has for its goal the introduction into general public use of gaseous products, made by cheap and rapid processes and on a gigantic scale, distributed throughout our cities and towns in distribution-systems, which shall be proportionately gigantic, and sold at prices which will bring such fuel within the means of the poorest householders.

Personally, for ten years past, the writer has never failed, on occasions public or private, to urge his belief that the realization of this idea, deemed by him a certainty of the future, will bring about important revolutions in human affairs. As once publicly stated, he looks upon it as "the next great stride

in civilization," destined to rank at least with the introduction of steam power, railway transportation, the Bessemer process, the electric telegraph, the articulating telephone, and the like events.

The time the writer has long looked for has now at length come, when "practical men" and "moneyed men" are working together, and organizing, on the basis of the production of gaseous products adapted or adaptable for *fuel*, without direct reference to the use thereof, in a merely vehicular way, as media of convection for illuminating hydrocarbons; this latter being regarded as only subordinate and not essential to the grand aim in view. This, of course, brings into prominence any improved plan that may be found to exist, of generating such gases cheaply and rapidly; and hence what is known as the "Strong Process" at once claimed and has received great and deserved attention.

It is, probably, not necessary that this process should now be described in detail, as Professor Silliman, at the Montreal meeting, explained it. Gentlemen desiring details will find them complete in a printed pamphlet, obtainable from M. H. Strong, Esq., 13 Park Row, New York city. The writer is now, for the first time, occupied in investigating, chemically, the operation and the products of the Strong apparatus; but this undertaking is yet too recent to have furnished many complete results. The present statement is, therefore, to be looked on as preliminary only. Experiments to determine directly the *practical* thermic effectiveness of the Strong gas—which is, for most persons, the point of most immediate interest—have not yet been made, though it is possible that some of them may be so in time to be printed with this paper. Results are here given, however, of careful analyses, together with determinations of density, of a sample of Strong gas; the two sets of figures agreeing with each other, as is essential to reliability. The data are thus at length at our command for accurate *theoretical* computations of the thermic energy, or energy of combustion of this gas.

The sample of gas examined is one now contained in a holder of 10,000 cubic feet capacity at Mount Vernon, Westchester County, N. Y. It was made some six weeks since, and has, therefore, stood for this period over water, though apparently without appreciable change in composition. The materials used were egg coal, one-third, and waste anthracite screenings, two-thirds. Two good analyses of this gas gave, for 100 volumes:

TABLE I.

	No. 1	No. 2.	Mean.	Density-computation.
Hydrogen	44.55	45.05	44.80	× .0006930=.0310464
Carbonic oxide	40.29	39.79	40.04	× .0096740= 3873470
Marsh gas	4.76	4.85	4.80	× .0055300=.0265440
Carbonic acid	1.11	1.21	1.16	× .0152000=.0176343
Nitrogen	9.10	9.18	9.14	× .0097134=.0887805
Oxygen	.19	.09	.14	× .0110560=.0015478
	100.00	100.17	100.08	

Computed density at 32° F. =.5529000
Four determinations of density by effusion at 32° F., gave a mean =.5512

Traces of sulphuretted hydrogen, doubtless present in this gas when first made, have been removed by the water. There is proof that the holder has otherwise preserved the gas well in the small amount of oxygen present. No diffusion outward could occur, without inward diffusion of air, carrying oxygen.

The above constitutes what may be regarded as a *verified* gas-analysis, agreeing with the experimental density.

In the next table will be found the

percentage composition by weight as well as by volume; also the thermic value, in Centigrade and Fahrenheit units, or degrees to which one pound (7000 grains) of water may be theoretically heated by one pound of gas.

TABLE II.

	By volume.	By weight.	Computation of thermic value per pound.
Hydrogen	44.80	5.62	×344.62°=1935°
Carbonic acid	40.04	70.06	× 24.03°=1683.5°
Marsh gas	4.80	4.80	×130.63°= 627°
Carbonic acid	1.16	3.19	
Nitrogen	9.14	16.06	Centigrade—4245.5°
Oxygen	.14	.28	Fahrenheit—7642°
	100.08	100.00	

One of the striking results of this analysis is the extremely large amount of nitrogen shown. This could only have come from air introduced in the process of manufacture, by reason of imperfection in the experimental apparatus used. This apparatus is so small that the duration of each heat or successive run is necessarily very short—only ten or twelve minutes, instead of thirty or more, as in a working apparatus. The contents of the generator, in products of combustion with air, after each blowing-up with the latter, are swept on to the holder, together with the gases or products of combustion with steam. The former bear, therefore, to the latter a considerable proportion, appearing to multiply the nitrogen threefold above its proper proportion.

It is the writer's expectation that a perfected fuel-gas production—such as will soon be brought about, now that this manufacture is to be prosecuted on a large scale—will give us a gas containing uniformly less than 3 per cent. of nitrogen by volume, or from 5 to 6 per cent. by weight. The nitrogen in the anthracite yields at most ½ per cent., while that in the steam is inappreciable. Such a gas as this, made with a perfected Strong generator, will have, as shown by the above analyses—taking into account that 6 per cent. of nitrogen implies an ingress of 7.5 per cent. of air, or 1.5 per cent. of oxygen, which has, therefore, given us 3 per cent. of the carbonic oxide present—the following composition:

TABLE III.

Computed composition of crude Strong gas, from large working generators.		Reduced to 100 volumes.	Density computation.	Computed to 100 parts by weight.	Thermic value. Centigrade.	Thermic value. Fahrenheit.
Hydrogen	45.0	49.6	.0344	6 81	2,347°	4,225°
Carbonic oxide	37.0	40.8	.3947	78.11	1,877°	3,379°
Marsh gas	5.0	5.5	.0304	6.02	786.5°	1,415°
Carbonic acid	1.0	1.1	.0167	3.30	....	......
Nitrogen	2.7	3.0	.0291	5.76	....	......
	90.7	100.0	D. = .5053	100.00	5,010.5°	9,019°

Or, in round numbers, such gas will have, at 32° F., half the density of air, with a total thermic power of 5000° C., or 9000° F. per pound. (At 60° F. the density will be only .4482). This standard should be obtained in fair practice; and, with good apparatus in good order, may be reasonably and uniformly pected for *crude Strong fuel-gas* made from two-thirds screenings, and one-third egg and *unpurified.*

A document referred to below contains

evidence that even the imperfect Mount Vernon apparatus has produced gas containing far less nitrogen than the sample analyzed by the writer. This is an analysis by the learned chemist, Dr. P. H. Vander Weyde, as follows:

Hydrogen	52.3
Carbonic oxide	39.4
Marsh gas	4.3
Carbonic acid } Nitrogen }	4.0
Sulphuretted hydrogen	undetermined.
	100.0

The carbonic acid and nitrogen are here summed up together; but if the carbonic acid be assumed as found in the analyses of the writer the nitrogen becomes 2.9 per cent. only by volume.

The next tabulation represents the product as it will be after purification with lime to remove the 3.3 per cent. by weight of carbonic acid.

Table IV.

	By volume.	Density-computation.	Composition by weight.	Thermic value (Fahrenheit) per pound.
Hydrogen	50.15	.03475	7.04	4367°
Carbonic oxide	41.25	.39905	80.76	3493°
Marsh gas	5.56	.03075	6.22	1462°
Nitrogen	3.04	.02953	5.98	.....
	100.00	D. at 32° F. = .494 D. at 60° F. = .437	100.00	9322°

As less than 2 per cent. of the nitrogen out of the 6 per cent. by weight comes from the anthracite, a full economic view of this product requires further that, as 4 per cent. of the nitrogen costs nothing, it should also be deducted. Should it be found possible, therefore, to exclude air wholly, the thermic value of the resulting fuel-gas would be

$$9322^\circ + 4 \times \frac{9322^\circ}{100-6} = 9719^\circ$$

So perfect a result as this is not, however, at present, counted on.

COST OF PRODUCTION OF STRONG FUEL-GAS.

Pending the experimental investigations on the thermic value of the Strong gas, which the writer has projected, and is now arranging to make, it may be of interest to present some points derived from an important document (not previously before the public), which contains results of experiments upon the amount and cost of production of gas from the experimental Strong apparatus at Mount Vernon, by highly competent gentlemen entirely disinterested in every way. These gentlemen were Charles A. Stanley, Esq., Assistant Superintendent of the Brooklyn City Gas Works, and Professor William D. Marks, of Philadelphia.

The report referred to was made by them August, 18, 1877, to the Brooklyn City Gaslight Company. A copy of this, evidently a *fac-simile* made by impression, has come into the writer's possession. It is this document that was found the valuable analysis, cited above, of Dr. Vander Weyde. There is copied, also, in this report, a series of experiments previously made by an agent of, and for, Walter E. Lawton, Esq., of No. 12 Cliff street, New York, of which latter experiments Messrs. Stanley and Marks remark that they do not give as good an average as their own. Mr. Lawton has since, it is understood, become interested as a promoter of the fuel-gas movement.

In each of these two series of experiments, consisting of a succession of ten-minute runs, the yield of gas ran down gradually. Stanley and Marks obtained at first 1647 cubic feet gas from 63 pounds anthracite, and 1627 cubic feet gas from 63 pounds anthracite. In the Lawton series were obtained 1718 feet from 60 pounds, and 1554 feet from 60 pounds, the mean of these four being 1000 feet from 37.5 pounds; while the tenth runs respectively gave Stanley and Marks 1050 feet from 45 pounds; Lawton, 1042 feet from 45 pounds; the

mean of the last two being 1000 feet from 43 pounds.

Messrs. Stanley and Marks state, however, that "the generator and flues are so small, and the doors so arranged, that the apparatus admittedly cannot run without choking from clinkers." Also: "The apparatus, being the first of its kind, is not so conveniently designed as it might have been; much trouble with clinkering of the fire might be avoided by a design which would admit of stirring the fire." Other imperfections, obvious to these skilled engineers, and readily remediable, are alluded to.

The writer feels perfectly justified, through his past experience in cases of this sort, which has been exceptionally extensive, in estimating the yield obtainable in a well-constructed working apparatus (such, for example, as is now erecting at Yonkers) from the *best* work actually accomplished with this imperfectly constructed experimental plant; which is, as above, 1718 feet from 60 pounds, or about 1000 feet from 35 pounds coal. For safety, however, let us rather adopt the *four best runs*, two of each set; giving 37.5 pounds per thousand as the yield that may be expected to be fully and continuously realized on a large scale from a perfected plant. The coal used by Stanley and Marks was about one-third egg (used in the generator), worth at that date $5 per ton, and two-thirds of a mixture of dust and pea (in the hopper), worth then $1 per ton. Strong prefers, for obvious reasons, that no pea coal should be used, but all dust or fine screenings, in the hopper; this two-thirds being, or rather including, that portion of the carbon which mainly reacts with the steam, and from which the gas therefore mainly proceeds. Such screenings—an unlimited supply of which, for a century, is procurable for the mere cost of transportation—may be rated at $1 per ton at most, while egg coal is now about $4.25, though to avoid cavil we will retain the valuation of $5. These data give, for 37.5 pounds anthracite per 1000 cubic feet of fuel-gas:

$$\frac{2240 \times 37.5}{\frac{500}{3} + 2\,\frac{100}{3}} = 3.605 \text{ cents; say } 3\tfrac{2}{3} \text{ cents.}$$

The minimum estimates of the Society of Gaslighting, discussed below, put this item at 75 pounds of anthracite at $4.50 per ton, about 15 cents per 1000 feet, which is 400 per cent. above the actual expense shown in the Mount Vernon generator, with a clean fire.

It is to be understood that the 37.5 pounds of anthracite includes *all* coal used for steam-making, and all other purposes in the Mount Vernon apparatus when working fairly. This is expressly set forth by Stanley and Marks; whose allowance, however, for coal consumption, being deduced from the *average* working of the partially clogged generator, during the whole succession of runs, sums up *six cents* per 1000 feet for coal (egg rated at $5). As to labor, in operating the experimental plant, Stanley and Marks state that an engineer at $2.50 per day, a stoker at $1.75, and a helper at $1.25, were occupied four hours and thirty-four minutes in making 13,035 feet of gas; hence they make for labor 17.5 cents per thousand; allowing, however, that "there can be no doubt that, if the process is worked on a large scale, the labor cost can be reduced much below this."

On this point the writer learns from James S. Pierson, Esq., the engineer engaged in constructing the new Strong Gas Works at Yonkers, that he expects these same three men to run at least four working generators, making 200,000 feet each per day of 10 hours, in all 800,000 feet, which will bring down the cost of labor per thousand to less than *two-thirds of a cent.* It is preferred to multiply this for safety, and call it a cent and a half per thousand. As to the statement of 3 men to 4 generators, the writer finds no difficulty in crediting this, as to his own personal knowledge 4 men do easily operate 6 Lowe generators.

Lime, and handling thereof, for purification of the fuel-gas, may cost, as a high figure for a moderate-sized plant, two cents more per thousand. We have, then, for the probable total cost of putting purified fuel gas, by the Strong system, into the holders: $3.67 + 1.5 + 2 =$ say *seven cents and two-tenths per thousand feet.* Mr. Strong's own estimate has been *eight cents,* which is evidently an entirely safe one.

This will produce gas, as shown above,

of 9322° F. per pound; and as one pound of such gas at 60° F. contains (D.=437) just about thirty cubic feet, one cubic foot contains 311° F. of thermic power. The writer has reasons, from facts on record, to anticipate that, for heating water up to boiling, suitable burners will utilize for us at least 70 per cent. of this, or say 230° F. per cubic foot. When heating air, as in warming houses, even a larger proportion will be made available.

Among the newer chapters in the history of what has been called the Fuel-Gas War, is a pamphlet, issued recently by an association of gas engineers of the first rank, entitled "The Waste of Energy in the Production of Water Gas." To this document are signed the names of the members of this society, by way of indorsement.

The writer, on having his attention lately called to this pamphlet, found with surprise its arguments to be based almost wholly on assumptions which do not bear examination. Of these fallacies only a few of the more important can be selected, as a complete discussion of this document would probably more than wear out your patience.

The manifesto of the Society of Gas-lighting begins by promising strict and impartial scientific discussion, and proceeds at once, then, to the usual reiteration of hackneyed denunciations of water gas. First, it is *not new;* reference being made to the well-known English patent to the Kirkmans, of July, 1852, in ignorance of the practically identical previous patent to F. C. Hills, of January, 1852, and of the closely approximate patents of 1845 to William Pollard and John Constable, with the American patent to George Michiels, also of 1845. The Kirkman patent serves to introduce what seems to be a declaration of the intention of the Society of Gaslighting when it shall come that its members shall be forced to make water gas, to do so without reference to existing patent-rights, assuming and asserting, in these words, that "the Kirkman process is that most largely used in this country," at the present day."

We next find reproduced the exploded assertion that water gas "was condemned and abandoned in France on account of it containing from 30 to 40 per cent. of the extremely poisonous carbonic oxide gas."

On the other hand, Dr. Adolphe Wurtz, one of the most eminent and learned of living chemists, wrote from Paris, June 12, 1878, in comment upon an investigation of the writer of one of the improved processes, and the attacks that were made upon it, as follows: "The use of water gas has never been prohibited in France, and if the numerous processes which have been indicated for its production have been abandoned, or have received only a restricted application, the cause is principally due to the circumstance that the technical and economical conditions of the production have, up to the present, been very unfavorable." He refers, of course, to the non-occurrence in France of indigenous materials suitable for this manufacture. He also says that "the danger (that is, of carbonic oxide in gas for domestic use), which could only produce ill results exceptionally and through fatality, has been exaggerated, and should not be taken into consideration." In reference to this part of the controversy, but two remarks will at present be offered.

Most gases, except pure air, are unfit for purposes of inhalation or respiration, and carbonic oxide shares this unfitness with others that are found in gas from gas coal. It is not, however, the purpose of the makers of fuel gas to introduce an article for purposes of respiration. Nor is it intended to serve out to the public an *inodorous* gas, as has been averred, thus increasing the liability of accident. All fuel-gas made for household or other uses will be found to possess odors even more characteristic and alarming than that of gas-coal gas. As to those cases coming under the head of fatalities, such as blowing out the gas in a sleeping-room, these will occur with all gases. So, also, will men go to sleep upon railroad tracks; but this has not been deemed an argument against the railway system. So will coal miners unlock and open their safety lamps; but no one therefore demands that coal mining be discouraged or discontinued. Moreover, carbonic oxide is actually now used, and far too largely and generally, for purposes of respiration; this being, in point of fact, one of those very lamentable defects of

our present household organizations which *fuel-gas is destined wholly to cure.* The leakages and irregularities of our coal stoves, heaters, and furnaces, which force us now so often to inhale carbonic oxide—together with other gases, such as *sulphurous oxide*, a compound more poisonous, beyond all comparison, than carbonic oxide—will be entirely avoided by the adoption of fuel-gas heaters of proper construction.

Again, it has been previously pointed out by the author, that risks from fire and explosion will be greatly less with carbonic oxide than with gas-coal gas, which latter contains from one-third to one-half of marsh gas, or *fire-damp*, this being much the most explosive of all common combustible gases.

The document emanating from the Society of Gaslighting then proceeds to its main business, which is to prove that, in the conversion of carbon into fuel-gas, less than one-third of the thermic power of the carbon is left, more than two-thirds being necessarily wasted or dissipated altogether. This is a great advance on the earlier arguments of the opponents of fuel-gas, who only went so far as to assert that, as water, when unburned, must necessarily absorb just as much energy as its hydrogen engenders when burned, therefore the whole project must be unwise, unscientific, unpractical, and utopian. Not longer ago than 1873, technical journals, held in high and just esteem as educators of the public in technical matters, and of great circulation, used language indicating that this sort of thing was to be classed with perpetual motion and the like delusions. To illustrate, the following may be exhumed: "Notwithstanding the reiterated statement in the *Scientific American*, and other exponents of practical science, that it is impossible to utilize water as a fuel, because it takes as much heat to decompose it into oxygen and hydrogen as one can get from the recombustion of these gases, men continue to waste their time in inventing apparatus to accomplish it."

It appears to have been almost universally conceded that the undeniable proposition, founded on the conservation of energy, implied in the last paragraph, in enforcing the conclusion that *some expenditure* must needs accompany the manufacture of water gas, made it self-evident that all such schemes were unworthy the attention of the public and of practical men. The unbiased portion of the public has now begun, however, to comprehend that the existing practical conditions really, and indeed overwhelmingly, neutralize this seemingly sound and scientific argument; that the economy of use, the controllability, purity, cleanliness, healthfulness, safety, comfort, uniformity, indestructibility, reliability, easier confinement and storage, and other merits of fuel-gas will justify, if necessary, *considerable expenditure* in the making of it; and that the assumed application to this case of the grand truth of the conservation of energy involves a practical fallacy.

A new and great change of base on the part of the enemy appears, therefore, to have been decided upon; and in this pamphlet the attempt is deliberately made to obtain credence and currency for an asserted demonstration—that the expense or "waste" in converting the thermic energy of carbon into a gaseous form must needs be something like two-thirds of the raw material or solid fuel started with!

First. There is presented a *theoretical* computation.

Anthracite is stated to have a total theoretical thermic power per pound of 13,000° F. In reality, 14,000° is nearer, but it is probably not worth while to correct this now. Its *practical* value (for steam purposes, for example) is rated, however, as low as 6000°F.* For making fuel-gas, it is claimed that steam of as high a pressure as 100 pounds, say 7 atmospheres, is essential, the total heat of which is rated at 1153.4° F. per pound, which is low (1182.5° being about true, according to Trowbridge), but for simplicity this may also be admitted. 16 pounds of carbon and 24 pounds of water (as steam) are said to make 1000 cubic feet of equally mixed hydrogen and carbonic oxide, which is near enough for 60° F. Such mixture, in equal volumes, if it were obtainable, would weigh 40 pounds, and contain $2\frac{2}{3}$ pounds hydrogen and $37\frac{1}{3}$ pounds carbonic oxide. According to the admitted conservation-

* For reasons apparent to an expert reader, they nevertheless rate *coke*—containing, as is well known, from 7 to 10 per cent. less carbon than good anthracite—at a practical value of 10,970° F. per pound.

of-energy theory, this hydrogen, in burning (from 32° F.), engenders $62{,}500° \times 2.66 = 166{,}250°$. Such temperature must therefore be supplied by combustion of carbon, in order, theoretically, to unburn or decompose the water from which the hydrogen proceeded. It is, however, necessary to concede that the 16 pounds carbon, in burning to carbonic oxide with the oxygen of the steam, furnish $4450° \times 16 = 71{,}200°$; so that the amount of additional carbon, or rather, anthracite, required theoretically, at 13,000° per pound $= \frac{166.250° - 71{,}200}{13{,}000°} = 7.31$ lbs. The process of decomposition of steam by incandescent carbon is very strangely called *dissociation*. It may much more appropriately be called *combustion*, but we will not quarrel now with mere obscurities of language. So far, except fractional variations of data some of which may about balance each other, all is rational. And the result or product of the operation is 40 pounds of mixed hydrogen and carbonic oxide, but, theoretically, *at the temperature of* 32° F. An addition to the anthracite is, therefore, evidently necessary, determinable (with any degree of precision) only by experiment, representing what is necessary to heat the 40 pounds of gas, together with any *excess of steam* accompanying it, up to the temperature, above 60° F., at which they issue from the generator. This, at $500° - 60° = 440°$, in the Strong system, *may* be (see below) something under a pound; say .9 pound of coal. Then $16\frac{16}{9} + 7.31 + .9 = 26$ pounds of anthracite, in all.

This amount of anthracite, burned directly, has the theoretical value, $26 \times 13{,}000° = 338{,}300°$ F.; while 40 pounds of purified gas obtained therefrom, as above, in the Mount Vernon generator, have, acccording to the writer's analyses (see Table II.), deducting, of course, the 15 per cent. (at least) of nitrogen by weight which is not derived from the anthracite, the value $\frac{40^2}{40 - (15 \times 4)} \times 7642° = 359{,}633°$.

Here are two *theoretical* figures, which are directly comparable. Even if the value of 14,000° be assigned to the anthracite, we get then for total anthracite required, 25.4 pounds, and for its theoretical value, $25.4 \times 14{,}000° = 355{,}600°$ F., which is still some 4000° below the theoretical value of the Strong gas, theoretically obtainable therefrom. This curious fact is due, in some measure, to the considerable thermic value of the 5 per cent. of marsh gas present in the Strong gas, of which the Society of Gaslighting takes no account.

In the pamphlet, an addendum, ostensibly corresponding to the above, is made to the amount of anthracite theoretically required, in settling which "dissociation" is again mentioned, and to which the writer finds himself unable to attach any rational meaning whatever. The paragraph is as follows: "The temperature at which the dissociation of water takes place being 2192° F., according to Deville, the gas leaving the generator at this temperature, unless there be some method of utilizing the heat, carries off in heat, the temperature of the gas at the holder being 60° F.," an amount of the heat summing up 39,041° F. It seems to be asserted that the "temperature of dissociation" is that at which the gases *must* leave the generator. Now, while 2192° F. is less than half the temperature of dissociation *under constant volume*, according to estimates of Bunsen and Deville (4500° F., or higher), Deville obtained dissociation *under constant pressure* (that of the atmosphere) at some 1600° F. But it is wholly impossible to discern what we have to do with dissociation at all, or with any temperature, except the mean degree at which the products do actually leave the generator, of which more below.

The theoretical anthracite of the Society of Gaslighting adds up, including that which they insist on, for purposes of dissociation, to 28.31 pounds. Even this, at 13,000°, is theoretically worth only 368,030° F., not yet much above the theoretical value of the fuel-gas yielded by it theoretically (as above, 359,633°).

Second. The Society of Gaslighting estimates the amount of anthracite "practically required to produce 1000 cubic feet" of fuel-gas.

The assertion is started with, that this case is one parallel with that of the waste of thermic energy in the steam engine; rated in the pamphlet at nine-tenths of

the fuel. There is no parallelism whatever between the two cases. Thus, where shall we discover, in the fuel-gas process, anything parallel to the loss of energy in exhaust steam? To consider the fanciful arguments brought in at this stage of their figuring will somewhat tax your time and patience. It is first asserted that, instead of 24 pounds of water, as steam, being needed to make 1000 feet or 40 pounds of gas, 50 pounds of steam at least are necessary, or an excess of 26 pounds, which must accompany the produced gases, carrying off an immense quantity of heat, which, as asserted, is necessarily wasted. Even were this true, it would be easy to save much of this, if at the temperature asserted, 2192°, or any other, by simply passing it through the flues of a boiler, and bringing it down to 300° F. or thereabout. But the writer has only to refer here to the record, which shows that in the Lowe process at Utica in 1875, the amount of this excess of steam in the products, as they come from the generator, was determined by him by quantitative analysis, as only 10,772 grains, or 1.6 pounds per 1000 feet; thus increasing the amount of steam to be made and used to only 25.6 pounds. Therefore, the amount of coal required to make this steam, which they state at $\frac{1153.4° \times 50}{6000°} = 9.61$ pounds, is really more nearly $\frac{1153.4° \times 25.6}{6000°} = 4.92$ pounds. In the Strong system it appears unlikely that any appreciable excess of steam could remain in the gaseous products, as these, after their formation, are subjected to a secondary operation of transmission downward, through an incandescent mass of anthracite.

The 16 pounds of carbon is asserted to need 20 pounds of anthracite to supply it, an obvious exaggeration, 18 pounds being an ample allowance; if, indeed, in the case of this figure, any allowance is called for, except for impurity in the anthracite, which would bring it below 17 pounds; 18 pounds will, however, be conceded. The temperature of the gas, as it leaves the generator, is, *at one stage of* the Lowe process, sometimes as high as 1200° F. (its *mean* temperature, however, being as yet undetermined), but in the Strong experimental apparatus the eduction-pipe does not reach more than 500° F., so far as the writer's observation has extended, or as he can learn by inquiry from others. In the Strong process, then, the possible loss arising from this source (assuming that no means are taken to save this residual heat) may be computed as follows:

Hydrogen..............	2.66 pounds	×	(its sp. heat) 3.4046	× (500°−32°)	=4,238°
Carbonic oxide.........	37.34 "	×	" " .2479	× "	=4,332°
Steam..................	1.60 "	×	(its total heat at 500°)	1200°	=1,920°
Possible loss of heat per 1000 cubic feet of gaseous products,					=10,490°

To convert this into practical anthracite equivalent, the Society of Gaslighting would divide it by 6000, ignoring entirely the fact that this heat may fairly be all regarded as *recovered heat* of the products of combustion, recovered by the action of the regenerative appendage used in both the Strong and Lowe systems. Even if this be not insisted on fully, as the writer believes justifiable, yet the divisor 6000 is here of course absurdly inapplicable, and the lowest divisor that could be rationally adopted is the full assumed theoretical value, 13,000°. This makes the anthracite consumption due to residual heat $=\frac{10,490}{13,000}=$ .8 pounds; a figure to be substituted for the total figure ciphered out by the Society of Gaslighting, which is 8.35 pounds. Our total estimate of anthracite consumption in making 1000 cubic feet of Strong fuel-gas is then: $4.95+18+.8=33.7$ pounds. This figure may be usefully compared with the best actual result on record of the very imperfect experimental plant at Mount Vernon=35 pounds; two-thirds of which were screenings.

According to the Society of Gaslighting, such weight of anthracite is practically worth $33.7 \times 6000° = 202,200°$ F., while 40 pounds Strong gas, made therefrom, as previously computed, is worth, *theoretically*, 359,633° F.; difference=157,433°.

It remains to be seen how large a percentage of this total theoretical value of 1000 feet of fuel-gas will be available when this gas is used for heating, cooking, motor, metallurgical, and other uses. It may be pointed out that only 55 per cent. of utilization = 195,982° F., pretty nearly obliterates the "waste of energy" of the Society of Gaslighting, when its own valuation of anthracite coal is adopted. Now it happens that 55 per cent. is just the proportion of the theoretical heat of gas-coal gases, stated by a distinguished gas chemist, Dr. Wallace, of Glasgow, the gas examiner of that city, to have been recently obtained by him in experiments in heating water, without the use of Bunsen burners. Moreover, our own very ingenious and industrious gas expert, Mr. Goodwin, of Philadelphia, has recently published experiments showing that, under the conditions of the Bunsen burner, some 25 per cent. less gas will do as much work in heating water below boiling, as when ordinarily burned.

Before leaving the pamphlet of the Society of Gaslighting, it is necessary to refer to the citation therein of some experiments by E. Vanderpool, Esq., and Dr. A. F. Schuessler, who made, as they state, a mixture of hydrogen 65 and carbonic oxide 35 per cent., and gave a determination of its thermic value as 136.6° F. per cubic foot. As *pure* hydrogen and carbonic oxide, in these proportions, must possess, at 60° F., a value per cubic foot of 324.5° F., this experimental result shows a utilization of but 42 per cent. of the total power. This, the pamphlet pointedly remarks, "may be taken as practically reliable." But, as no analytical or other evidence is presented of the absence of foreign inert gases from the mixture made, this surprisingly low result certainly justifies the presentment of the hypothesis of the ingress of such inert gases, in some such way as to evade the vigilance of these gentlemen. Few of the methods for the preparation of the two gases operated on yield products of even approximate purity.

The same experts also give a determination of the thermic value of gas-coal gas ("ordinary 16-candle gas") as 318° F. per foot; while in another part of the pamphlet (what is presumably) the same gas is rated at 660° F.; estimates of its economy as compared with so-called "water gas" being based on the latter figure, to the neglect of the former, arrived at by actual experiment.

The writer feels compelled also to refer to the fact that, in quoting the figures of Sarnstrom, from the correspondence of George S. Dwight, Esq., from Stockholm, Sweden, as given in the *Engineering and Mining Journal* of August 30, 1879, the writer or writers of the pamphlet would seem to have made an oversight, or selected figures to suit their argument. The result of comparing the Strong gas, as made at Stockholm, with gas-coal gas, are given by Mr. Dwight in three different forms, two of which agree with each other, and not with the third, which latter inferentially, therefore, involves some miscalculation. The two which agree give the fuel-gas a value of more than half that of the special gas-coal gas compared, while the other (the one selected and used in the Society's pamphlet) makes the gas-coal gas 2.2 times as powerful.

The following wonderful statement from this pamphlet of the Society of Gaslighting may help to account for the mental obliquities which must have contributed to the fallacious reasoning and untenable conclusions found therein: "A glass globe exhausted of air, under constant pressure and temperature, can be filled with the vapor of water, and there is still room for the globe full of alcohol vapor, and then there is still room for the globe full of ether vapor—and we might go still further." We might, in all humility, inquire what the gas analysts are to do, now that this new law of nature, subverting all their processes, has been discovered by the Society of Gaslighting?

A subsequent paper will be submitted on the relations of fuel-gas and the Strong system to *illuminating gas*, and to the closely related Lowe system of making the latter, in which facts and statistics of great public interest, now in the course of collection and preparation, will be brought forward.

ON THE MEASUREMENT OF DISTANCES IN LEVELING AND SURVEY OPERATIONS.

By Mr. HENRY V. WHITE.*

From "The Engineer."

The object of this paper is to describe the principle and practical utility of a new self-measuring arrangement for calculating distances, capable of being attached at a nominal expense to the ordinary dumpy level or theodolite, by means of which the range and serviceable value of these instruments can be much increased. It is believed that by this arrangement the necessity of measuring with the chain in leveling for sections can be dispensed with. Moreover, the country can be surveyed at the same time with great accuracy, the combined operations being effected with rapidity and ease, while the results obtained will be found perfectly reliable for any surveys made for engineering purposes. Also, in taking flying levels on an open plain destitute of landmarks, the position of each spot where the staff has been held can be defined with great facility and accuracy. It is, moreover, claimed that while on uneven ground horizontal chain measurements are unreliable, the results thus obtained will be equally reliable whether the ground is flat or uneven.

The idea in the telescopic arrangement of estimating the distance of an object by means of the instrument itself is not original. The different distances require corresponding alterations in the focus of the object glass. Hence when the object is near the eye-tube must be drawn out, and when far pushed in. Dr. Brewster applied this fact to the measurement of distances, by having the eye-tube graduated accordingly. This, however, would vary for each observer, and, besides, the graduations would be so minute for appreciable distances as to be unreliable. The idea then suggested itself that if any suitable arrangement could be devised for estimating the distance of the staff used in leveling from the instrument itself, so as to dispense with the labor of chaining, it would commend itself to favorable consideration.

* Read before Institution of Civil Engineers in Ireland.

Now, in levels and theodolites the horizontal wire marks the intersection of the horizontal visual ray where it meets the staff when the bubble is brought to the center of its run, and is fixed in a diaphragm in the focus of the eye-tube and object glass.

In the following investigation the effect of the eye piece itself may be neglected, as the magnifying power affects in the same proportion both the image of the staff and the distance apart of the two new wires proposed to be fixed—one above, the other below the ordinary horizontal wire; these to be parallel to, and equidistant from, the latter, and in the same focus.

Let D = distance of staff from object glass, and d = that of conjugate focus; we have when f=that of principal focus

$$\frac{1}{d}+\frac{1}{D}=\frac{1}{f}$$

or

$$d=\frac{1}{\frac{1}{f}-\frac{1}{D}}.$$

Now, if s=height of image of staff formed before being magnified by the eye piece at the focus of the object glass, we have when S=height of staff

$$S : s :: D : d.$$

Let H=difference of staff reading between these new wires, and w=their distance apart; then $S : s :: H : w$ or $H : w :: D : d$; substituting for d we obtain

$$H : w :: D : \frac{1}{\frac{1}{f}-\frac{1}{D}}$$

or

$$w=\frac{H}{\frac{D}{f}-1}=\frac{Hf}{D-f}.$$

Hence

$$D-f=\frac{f}{w}\times H.$$

As $\frac{f}{w}$ is a constant, it is therefore

established that the distance of the staff from the object glass, less the focal length—which in ordinary instruments is about 12 inches—varies directly as the difference of readings between the upper and lower wires. To determine the actual value of $\frac{f}{w}$ when D − f was found by measurement, experiments were made as follows, and the results obtained under the circumstances also serve to prove the practical value of the proposed adjustment. The instrument used is by Troughton & Simms, and the distance apart of the new wires was made about $\frac{1}{8}$-inch. The ground chained was not particularly flat, and the weather was unfavorable. The day was cloudy with occasional gusts of wind, which vibrated the instrument, accompanied with rain. There was no plummet used with the staff. The measured distances in the first column happen unfortunately to be uneven numbers, as in the actual measurement the chain was started from the perpendicular of the diaphragm on the ground, instead of 2 ft. farther on, so as to start from the focus.

Distance (D − f).	Difference (H).	Distance (D − f).	Difference. (H).
Feet.	Feet.	Feet.	Feet
48	0.47	148	1.47
53	0.52	198	1.95
58	0.58	248	2.45
63	0.62	298	2.94
68	0.66	308	3.03
73	0.72	348	3.45
78	0.76	388	3.80
83	0.82	398	3.93
88	0.87	448	4.40
93	0.92	498	4.90
98	0.96	508	5.00

Here throughout, as would be expected, the difference of readings varies as the distance—taking to allow for unavoidable errors of observation a mean of the results obtained from the readings 100 feet apart between 98 ft. and 498 ft. distance, we have

Distance (D − f).	Difference (H).	Constant $\left(\frac{f}{w}\right)$
Feet.	Feet.	Feet.
98	0.96	102.0
198	1.95	101.5
298	2.94	101.4
398	3.93	101.3
498	4.90	101.6

The mean of these results gives $\left(\frac{f}{w}\right)$ for this particular instrument = 101.6 and since 101.6 × H = D − f, we have a difference of reading amounting to

1 ft. corresponds to 101.6 ft. distance
and of
$\frac{1}{10}$ ft. " 10.16 ft. "
and of
$\frac{1}{100}$ ft. " 1.0 ft. "

To apply this rule:

Suppose H = 3.57 ft.
then 101.6 × 3 = 304.8 ft.
10.16 × 5 = 50.8 ft.
1.0 × 7 = 7.0 ft.

362.6 = D − f.

From this it is evident that if we assume $\frac{2}{100}$ of a foot as the maximum error of observation likely to occur in estimating H in ordinary work, it will only give 2 ft. of possible error in the calculated distance; these slight inaccuracies would scarcely be sensible in practice, and would neutralize each other in numerous observations. Of course, in actual work, the distance should be taken from the center of the instrument itself, so that to D − f as calculated should be added (f + $\frac{1}{2}$ length of tube) = usually to 18 inches. The following table gives opposite the actual distances (D − f) as measured the results as estimated:

Ascertained Distance (D − f)	Difference (H).	Estimated Distance (D − f).
Feet.	Feet.	Feet.
48	0.47	47.6
53	0.52	52.8
58	0.58	58.8
63	0.62	63.0
68	0.66	67.0
73	0.72	73.1
78	0.76	79.1
83	0.82	83.3
88	0.87	88.3
93	0.92	93.4
98	0.96	97.4
148	1.47	149.2
198	1.95	198.0
248	2.45	248.8
298	2.94	298.6
308	3.03	307.8
348	3.45	350.4
388	3.80	386.1
398	3.93	399.2
448	4.40	447.0
498	4.90	497.8
508	5.00	508.0

The result of these figures leads to no other conclusion than that the proposed system of measurement is perfectly reliable, even where great accuracy is required; in the latter case, by selecting a calm, clear day, and using a plummet, the estimated distances would be found more reliable than any measurements made with the chain on ground perfectly flat. When the principle of the proposed system of measurement was developed, the results were forwarded to Dr. Haughton, of Trinity College, who very kindly looked over the papers, and made the important suggestion that the best method of finding the constant for each instrument would be from direct measurement instead of the staff readings. The author, however, has had no means of doing so with the necessary accuracy.

Two special cases present themselves for consideration in the use of the adjusted instruments—one when they are applied to measuring purposes only, the other when levels and distances have to be taken at the same time. In the former case, with regard to the level, it should be placed in adjustment so as to intersect the staff in the usual way, and here, when the ground is tolerably flat, it will always be easy to make the three wires intersect. This is evident when we consider that the usual staff is about 14 ft. long, and that the greatest difference in the readings obtained in these experiments was 5 ft.—an amount that would never be exceeded in practice. It will sometimes happen, especially when long sights are used and the ground is tolerably uneven, that the three sights will not intersect simultaneously; this will only occur when the horizontal wire crosses either nearly the top or bottom of the staff. In this case the tube may be slightly raised or depressed so as to obtain the extreme readings without sensible error, as the angle will be very small, and the resulting distance will be perfectly accurate if the staff is gently waved back and forwards at the same time so as to obtain the lowest readings, as then the axis of sight will be perpendicular to that object. In the other case, when levels and distances have to be taken simultaneously, when the horizontal wire crosses in this manner so as to obtain only two readings, the distance can still be calculated from their difference, as it will be proportional though not quite so accurately; otherwise by taking the horizontal reading for leveling, then raising or depressing the tube as described for the distance, and then moving and adjusting the instrument for a back sight without disturbing the staff, we are enabled to make the extreme wires intersect so as to obtain the usual accuracy. With the theodolite this movement in the particular case described would be unnecessary, as the angle of elevation or depression could be made again horizontal by means of the screws; also with this instrument along sloping ground or the side of a hill the telescope has only to be raised or depressed through a known angle, from which the direct and also horizontal distances can be found. When the slope is very sensible the staff should be placed at right angles to the axis of sight, instead of being made perpendicular to the ground. It is desirable, when leveling for sections by this method, always, where possible, to fix the center of the instrument throughout in the line of the section, or where this is not possible, the following method may be advantageously pursued: Let A, B, C, &c., represent adjacent points in the line of the section, at convenient visible distances from each other; two ranging rods should be set up first at points A and B; let P then represent the position of the instrument. We then have the distances PA, PB, and the angle APB; consequently the distance AB. For intermediate observations it is easy to set up the staff exactly in the line of range as often as may be necessary. If a, b, c, &c., represent the position of these intermediate points, we can estimate the distances Pa, Pb, Pc, &c., which lengths can be marked off on the plan with a pair of dividers from P, so as to intersect the line of range A B. Thus the position of each intermediate point of observation can be accurately determined. Next a ranging rod should be fixed at C, and the levels between B and C could be similarly taken. It is desirable to use three ranging rods in setting out a straight line, the back pole being continuously transferred to the front according as the work progresses. Curves would, perhaps, be best set out

by actual measurements of offsets taken from points in the straight lines produced. In the field book, for use to correspond with the proposed adjustment to surveying instruments, it would be only necessary to have two extra columns for recording the intersections of the upper and lower wires. There is sometimes a column for entering the magnetic bearing; this would be requisite, or for entering in the case of the theodolite the bearing, or angles made with fixed points.

ON THE DERIVATION, OR DRIFT, OF ELONGATED RIFLED PROJECTILES.

By A. G. GREENHILL, M. A., Professor of Mathematics to the Advanced Class of Artillery Officers.

From Proceedings, Royal Artillery Institution.

The principles of the preceding paper (see Sept. No. of MAGAZINE) afford an explanation of the drift of an elongated projectile to the right of the plane of fire.

If a projectile were fired in a vacuum, the axis would remain parallel to itself during the trajectory; no rifling would be required, and there would be no drift.

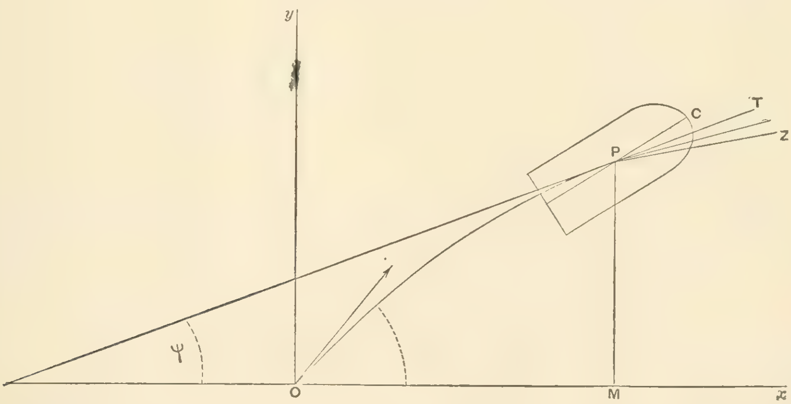
But it is observed that a projectile fired in air, with proper spin, has its axis in the tangent to the trajectory (very nearly) and that after it has reached a distance, short in comparison to ordinary ranges, from the muzzle, all "wabbling" ceases, being destroyed by the friction of the air, and the shot may be said, like a top, to "go to asleep."

Closer observation reveals that the point of the shot is a little above and to the right of the exact tangent to the trajectory; this deviation becoming more marked at the end of the trajectory.

A shot, even if perfectly centered, on issuing from the muzzle, has, after the first instant, its axis inclined to the tangent to the trajectory, in consequence of the curvature of the path of the center of gravity due to the action of gravity.

Take O, the origin, at the muzzle of the gun, Ox horizontal in the vertical plane of departure, Oy vertical, and Oz horizontal to the right of the plane of fire.

ELEVATION.



Let P be the center of gravity of the shot; x, y, z the co-ordinates of P; PC the axis of the shot; and PT the tangent to the path of P.

If there were no air, then PC would remain parallel to the tangent of the curve OP at O.

But the air causes a couple to act on the shot, tending to set the axis of the shot across the direction of motion: and this couple, acting on the shot (supposed to have angular momentum $c_6 r$) about PC, will deflect the axis PC to the right;

and after a few gyrations, which are destroyed by the friction of the air, the shot will move steadily, with its point permanently deflected slightly to the right.

PZ (the direction of the resultant momentum Z of the body and the medium) will remain constantly parallel to the plane xOy, because there is no impressed force perpendicular to this plane; and if a be the angle the axis of the shot makes with the plane xOy, and if u, w be the component velocities of P along PA and PC, then, as before,

$$c_1 u = -\mathrm{Z} \sin a,$$

$$c_3 w = \mathrm{Z} \cos a,$$

and therefore the velocity of P in the direction Oz,

$$\frac{dz}{dt} = u \cos a + w \sin a$$

$$= \mathrm{Z}\left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a.$$

Now, the couple acting on the body in the plane APC is

$$(c_1 - c_3)\, u w = \mathrm{Z}^2 \left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a;$$

and this, acting on the resultant angular momentum of the shot (which may be taken to be $c_6 r$, and indifferently about the axis PC or PT, since they are very nearly coincident) will cause the point of the shot C to descend so as always to be very nearly in the tangent to the trajectory; and therefore if the tangent at P makes an angle ψ with the horizon,

$$-c_6 r \frac{d\psi}{dt} = \mathrm{Z}^2\left(\frac{1}{c_3} - \frac{1}{c_1}\right) \sin a \cos a = \mathrm{Z} \frac{dz}{dt},$$

or

$$\frac{dz}{dt} = -\frac{c_6 r}{\mathrm{Z}} \frac{d\psi}{dt};$$

the negative sign being taken with $\frac{d\psi}{dt}$, because ψ is diminishing.

The resultant momentum Z may be put equal to $\mathrm{W}v$; where v is the resultant velocity in the trajectory, neglecting the momentum due to the motion of the air, which is small compared with $\mathrm{W}v$, the momentum of the shot; and therefore

$$\frac{dz}{dt} = -\frac{c_6 r}{\mathrm{W}v} \frac{d\psi}{dt} = -k^2 \frac{r}{v} \frac{d\psi}{dt}.$$

If the angular velocity r died away at the same rate as the linear velocity v, the fraction $\frac{r}{v}$ would be constant, and equal to the value it has at the muzzle, namely, $\frac{\pi}{na}$; $2a$ being the caliber.

Then

$$\frac{dz}{dt} = -\frac{\pi}{n} \cdot \frac{k^2}{a} \cdot \frac{d\psi}{dt},$$

and

$$z = \frac{\pi}{n} \frac{k^2}{a} (\varphi - \psi),$$

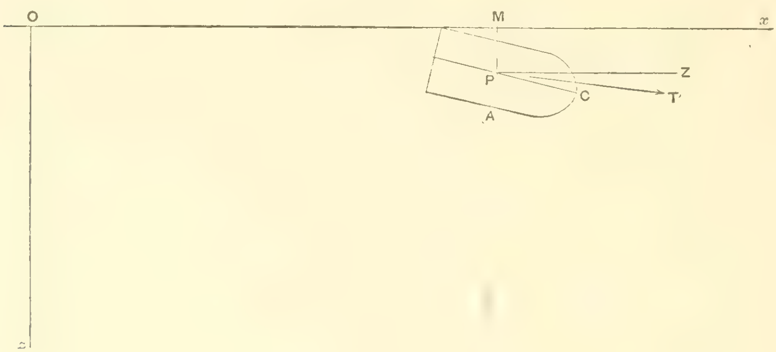
if φ is the circular measure of the angle of projection.

On this assumption the drift would be proportional to the change of direction of the motion, and the total drift to the sum of the angles of ascent and descent.

Using u now to denote the horizontal component of the velocity,

$$\frac{dz}{du} = -\frac{\pi}{n} \frac{k^2}{a} \frac{d\psi}{du} = -\frac{\pi}{n} \frac{k^2}{a} g \frac{w}{d^2} \frac{(1000)^3}{\mathrm{K}v^4}$$

PLAN.



For resolving horizontally and normally,

$$\frac{du}{dt} = -\frac{d^2}{w} K \left(\frac{v}{1000}\right)^3 \cos\psi,$$

$$v\frac{d\psi}{dt} = -g\cos\psi;$$

and dividing one equation by the other,

$$\frac{d\psi}{du} = g\frac{w}{d^2}\frac{(1000)^3}{Kv^4}.$$

In ordinary flat trajectories we may replace u by v, and then

$$\frac{d^2}{w}z = \frac{\pi}{n}\frac{k^2}{a}g\int_v^V \frac{(1000)^3}{Kv^4}\,dv,$$

$$= \frac{\pi}{n}\frac{k^2}{a}\frac{\pi}{180}(D_v - D_V) \;.\;.\;.\;.\; (1)$$

This integral has been calculated by Mr. Niven for velocities from 900 to 1700 f.s., and is given on p. 78 of Major Sladen's "Principles of Gunnery," and he is at present engaged in extending the range of velocities from 400 to 2500, using the values of K lately determined by Mr. Bashforth from the experiments carried out in 1878 and 1879. ("Report on Experiments made with the Bashforth Chronograph, &c.," Part II.)

But it is more usual to assume that the angular velocity r dies away very slowly, so that we may suppose it constant, and equal to the value it has at the muzzle, namely, $\frac{\pi V}{na}$; and then

$$\frac{dz}{dt} = -\frac{\pi}{n}\frac{k^2}{a}\frac{V}{v}\frac{d\psi}{dt},$$

or

$$\frac{dz}{du} = -\frac{\pi}{n}\frac{k^2}{a}Vg\frac{w}{d^2}\frac{(1000)^3}{Kv^5},$$

and

$$\frac{d^2}{w}z = \frac{\pi}{n}\frac{k^2}{a}Vg\int_v^V \frac{(1000)^3 dv}{Kv^5} \;:\;.\;.\; (2)$$

so that we shall require the integral $\int_v^V \frac{(1000)^3}{Kv^5}\,dv$ to be tabulated to calculate the drift.

The drift is proportional to $\frac{w}{d^2}$, which varies very nearly as the caliber, and also to $\frac{k^2}{a}$, which also varies as the caliber for similar projectiles; so that the drift varies as the square of the caliber for the same initial and final velocity. This explains why the drift is insensible in small arms.

The preceding explanation is substantially the same as that given by Prof. Magnus, except that the consideration of the *center of effort* is not necessary.

Magnus began by trying to explain the drift as due to the differences of pressure in consequence of the existence of a vortex round the shot; but this would make the shot drift to the *left*.

In the January, 1880, number of the *Messenger of Mathematics*, it is shown that a horizontal cylinder of density σ, revolving with angular velocity ω in infinite liquid of density ρ, and surrounded by a vortex, would, if left to itself, describe a cycloid from right to left, with mean velocity $\frac{\sigma-\rho}{2\rho}\frac{g}{\omega}$, and that if projected with this velocity would describe a horizontal straight line.

When a gas check becomes detached from the base of a shot, the forward motion is soon destroyed, but the angular velocity remains, and the gas check behaves in a similar manner to the above cylinder, and drifts to the left, with mean velocity $\frac{\sigma-\rho}{2\rho}\frac{g}{\omega}$.

For instance, in the 16 inch 80 ton gun

$$\omega = \frac{\pi}{n}\frac{V}{a} = \frac{\pi}{50}\frac{1600}{\frac{2}{3}} = 48\pi,$$

and for copper,

$$\sigma = 8.6,$$

while for air, $\rho = .001276$,

therefore

$$\frac{\sigma-\rho}{2\rho}\frac{g}{\omega} = 715;$$

the mean velocity with which the gas check will drift to the left, if it becomes detached from the base of the shell.

It is only in such a case as this, then, that we can assert (as on p. 589, Vol. X., "Proceedings, R. A. Institution") that the drift diminishes as ω the angular velocity increases; and the paradoxical result that the velocity of drift is infinite when the angular velocity is zero, only means that we should require to project the cylinder from right to left with infinite velocity in order that the path should not be curved.

From the preceding explanation we see that the drift is proportional to the

angular velocity. This explanation is rendered necessary by the unfortunate mis-statement on p. 589, which was written down hastily, and of which the incorrectness escaped notice till after the paper was printed.

We can gain an approximate idea of the amount of deflection of the point to the right, and above the tangent to the trajectory, by considering them separately, each being supposed small. For if a' denote the angle between the axis of the shot and the vertical plane through the tangent of the trajectory, then

$$\tan a' = \frac{c_3}{c_1} \tan a,$$

and the couple acting on the shot about the axis normal to the trajectory in this vertical plane

$$=(c_1-c_3)v^2 \sin a' \cos a';$$

which must therefore

$$=-c_6 r \frac{d\psi}{dt},$$

and therefore

$$\sin 2a' = -\frac{2c_6 r}{c_1-c_3} \frac{1}{v^2} \frac{d\psi}{dt}$$
$$=\frac{2c_6 r}{c_1-c_3} \frac{g \cos \psi}{v^3}.$$

Again, if β' be the angle between the axis of the shot and the plane through the tangent of the trajectory perpendicular to the plane xOy, the couple acting on the shot about the axis PA

$$=(c_1-c_3)\, v^2 \sin \beta' \cos \beta';$$

and this with our approximations must be put

$$=c_6 r \frac{da}{dt},$$

and therefore

$$\sin 2\beta' = \frac{2c_6 r}{c_1-c_3} \frac{da}{dt}.$$

If the rifling at the muzzle be just sufficient for stability,

$$\frac{2c_6 r}{c_1-c_3} = 8 \frac{c_3 c_4}{c_1 c_6} \frac{na}{\pi} \mathrm{V} = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V},$$

with the approximations employed; and then

$$\sin 2a' = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V} \frac{g \cos \psi}{v^3},$$

$$\sin 2\beta' = 8 \frac{n}{\pi} \frac{k_1^2}{k^2} a\mathrm{V} \frac{da}{dt};$$

and with our approximations we may put

$$\frac{da}{dt} = \frac{da'}{dt} = \frac{1}{v} \frac{d^2 z}{dt^2}.$$

TABLE OF THE INTEGRAL

$$\mathrm{Z} = \int_{400}^{v} \frac{(1000)^3 dv}{\mathrm{K} v^5} \text{ FOR INTERVALS OF 10.}$$

v.	00	10	20	30	40	50	60	70	80	90
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.00000	062649	119267	170511	216995	259273	297838	333092	365442	395171
5	422556	447828	471182	492813	512885	531533	548879	565043	580136	594258
6	607494	619908	631560	642504	652794	662474	671583	680158	688241	695871
7	703084	709905	716352	722444	728200	733648	738807	743685	748297	752654
8	756777	760680	764376	767865	771154	774255	777178	779937	782541	785006
9	787337	789537	791620	793593	795461	797234	798916	800512	802027	803467
10	804837	806139	807376	808545	809621	810582	811430	812189	812885	813539
11	814130	814695	815229	815737	816222	816687	817135	817561	817969	818360
12	818735	819095	819440	819771	820089	820395	820689	820972	821245	821507
13	821760	822004	822239	822466	822685	822897	823102	823301	823493	823679
14	823859	824034	824204	824369	824529	824685	824837	824985	825128	825268
15	825404	825537	825667	825793	825917	826038	826156	826272	826384	826494
16	826601	826706	826809	826909	827007	827103	827197	827289	827379	827467
17	827553	827635	827717	827797	827876	827953	828028	828102	828174	828245
18	828314	828382	828448	828513	828577	828640	828701	828761	828820	828878
19	828935	828991	829045	829098	829150	829201	829251	829300	829348	829395
20	829441	829486								

COMPRESSING STEEL.*

ON THE STEEL-COMPRESSING ARRANGEMENTS AT THE BARROW WORKS.

By Mr. ALFRED DAVIS, of London.

From "Engineering."

The unsoundness of steel castings, particularly in the case of ingots made by the Bessemer or Siemens-Martin process, has given manufacturers considerable trouble, and occasions much waste of material.

A good deal has been stated and written of late as to the cause of this unsoundness, which occurs principally at the upper end of the ingot; but it appears now to be pretty generally conceded that the defects proceed from two distinct causes: First, the existence of gases, generated at the point of transition from the fluid to the solid state, which are imprisoned in the form of bubbles when the surrounding metal becomes solid; and secondly, the existence of spaces formed by the natural contraction of the metal in cooling, by reason of the outer skin first becoming solid and refusing to follow up the interior portion of the ingot, which subsequently cools, and consequently occupies a smaller space.

Various systems, designed to cure this evil, have already been discussed before this Institution. The system, which is illustrated by the accompanying diagrams and models, namely, that of compressing fluid steel by the direct application of high-pressure steam, has recently been adopted by the Barrow Hematite Steel works, and by Messrs. Bolckow, Vaughan & Co., and has the merit of simplicity combined with efficiency. The arrangements adopted for the purpose are foundered upon those used by Mr. H. R. Jones, of the Edgar Thomson Steel Works, Pittsburgh, U.S., where the system has been worked for some years.

The exact plan in operation at the Edgar Thomson Steel Works is shown by the model (see *Engineering*, vol. xxviii., pages 84 and 85).

A high-pressure steam boiler is provided, and communicates with a receiver, which is attached to the side of the ingot crane, and which is furnished with a row of cocks corresponding with the number of ingot moulds. From these cocks strong india-rubber pipes convey the steam to the ingot moulds, which are arranged in the arc of a circle round the ladle crane. The metal from the ladle is poured through a loose pouring cup, which rests on a conical seat at the top of the ingot mould. As soon as the pouring is finished, this cup is removed, and a lid, having the steam pipe ready coupled to it, is placed on the top of the mould, and secured to it by a steel cotter. The cock on the receiver is then opened, and the steam allowed to act upon the metal until it has completely set. The result of this pressure is to make the ingot sensibly shorter than when cast in the ordinary manner, the difference, according to experiments, made at the Edgar Thomson Works, being from 1½ inches to 2 inches in a 5 ft. or 6 ft. ingot. The ingots when cold are perfectly level at the top, and there is no porous heads requiring to be cut off.

The arrangements adopted by the Barrow Steel Company differ somewhat from those in operation at the Edgar Thomson Works. These arrangements require only a very brief explanation.

The ingot moulds, which are of similar construction to those used by the Edgar Thomson Company, are placed in a row, within a dock or siding, the center line of which runs to the center of the pit. The metal flows from the ladle into a trough mounted upon wheels, and provided with runners at points corresponding with the centers of the ingot moulds when the trough is in position. This trough runs upon rails, placed on either side of the row of ingot moulds, and can readily be removed after the moulds are charged. Each mould is provided with a steam-tight cover, having a wrought-

* Paper read before the Mechanical Engineers, at Barrow.

iron pipe attached to it, furnished with a stop-cock. This pipe communicates at right angles with the main steam pipe, which runs parallel with the side of the dock. The junction of the branch steam pipes with the main is formed by means of a cast-iron sleeve-piece, with stuffing-boxes, to enable the covers, with their respective cocks and pipes, to be thrown back out of the way when not in use.

The boiler for suppling the steam has been constructed by Messrs. Daniel Adamson & Co. It is 3 ft. 6 inches in diameter and 9 ft. high, and is intended to be worked at a pressure of 200 lbs. per square inch.

An arrangement shown in the diagrams has not yet been put in practice; but the author believes that it has some advantages over other plans, and that it will prove an efficient method of applying the steam. The ingot moulds are fixed in position in the same manner as at the Edgar Thomson Works, but the method of securing the bottom joint of the mould is somewhat different. In one form of joint suitable for both the lid and base of the mould, V-shaped grooves are turned in the faces of the metal, care being taken that the diameters of the two grooves forming the joint are exactly equal. A ring of soft copper wire is then inserted and the two parts well keyed up with cotters, as before described.

The main pipe for supplying the steam follows the curve of the pit, about 12 in. from the side, and 18 in. below the surface of the ground. The branch steam pipe is of copper, coiled to give elasticity, and has at one end the lid of the mould, and at the other a stop-valve. The stop-valve is attached to a hollow sleeve, revolving on the main steam pipe, and is kept tight by means of stuffing-boxes. When not in use, the copper coil, lid, and coupling can be thrown back, and fall into a pit made for the purpose. This pit is covered over with an iron plate hinged at one side. No doubt other plans for applying steam pressure could be suggested, and various modifications will be uecessary to suit different conditions of working.

At the Cambria Steel Works, in Pennsylvania, an attempt was made to inject water through the cover of the ingot mould, after the metal had been poured. The heat of the molten steel, of course, generated steam, which acted as a compressing medium; a safety valve being provided and loaded to the pressure required. The disadvantages of this system, as compared with that now described, are sufficiently obvious; the complication of parts and the danger from explosions being very great.

The results obtained by the process of casting ingots under steam compression are highly satisfactory. Not merely is the ingot perfectly sound, but the action of the steam is such as to enable the men to work it earlier and in a hotter state than with the ordinary method, so that there is an appreciable increase in the output. The presence of the steam also acts beneficially on the sides of the mould, and causes it to last longer.

The pressure necessary to produce a perfectly sound ingot will depend upon the quality of steel to which it is applied. At the Edgar Thomson Works it is found that for ordinary rail metal 100 lbs. per square inch is sufficient. But for milder steel a higher pressure is needed; and since experience has proved that steam is readily dealt with at very high pressures, there does not appear to be any reason why 1,000 lbs. or 1,500 lbs. per square inch should not be applied if required. It is only a question of giving sufficient strength to those parts which are exposed to the pressure. As a matter of fact, the boilers designed by Mr. Loftus Perkins will carry a steam pressure of 2,000 lbs. per square inch with perfect safety. The question of making tight joints between the ingot moulds and covers with such high pressures is one of considerable importance; but there are several ways in which this difficulty may be overcome. In using steam at a very high pressure, the size of the supply pipe may be considerably reduced, and the mode of attachment greatly simplified; and since the amount of steam used is inconsiderable, the size of the boiler would be correspondingly small. As an alternative, in cases where high pressures are needed for the consolidation of fluid metals, the author proposes the use of compressed air. With this system a pressure up to 1,500 lbs. or 2,000 lbs. per square inch may be obtained without danger or difficulty, as is completely demonstrated by the topedo

practice at Woolwich, and by the experiments carried out by Colonel Beaumont, in connection with the use of compressed air for tramway locomotion.

The advantages of an elastic compressing medium in the consolidation of fluid metals, as compared with the hydraulic process, scarcely need to be dwelt upon. In applying hydraulic pressure a rigid piston is necessary; and the outer portions of the cooling mass (which are the first to set) must be crushed down, before the interior portions, which are still liquid, are reached by the pressure. A considerable amount of power is wasted in consequence. In addition, the fluid metal is forced against the sides of the mould, and in a contrary direction to that which it naturally follows in the operation of cooling. With steam or compressed air the operation is reversed; as soon as contraction commences, the entire ingot is surrounded by a uniform pressure, which continually follows up the natural contraction of the mass.

In conclusion, the author would suggest that the principle of elastic pressure, in connection with the consolidation of fluid metals, although at present applied to Bessemer ingots only, is well worth the consideration of those interested in the manufacture of all kinds of steel and iron castings, and particularly of heavy guns.

ON THE PRESERVATION OF BOILERS.

By Rear-Admiral C. MURRAY AYNSLEY, C. B.

From the Journal of the Royal United Service Institution.

The subject of the paper that I have the honor to read to-day is of so much importance not only to those afloat, but also to the thousands on shore who use steam power, that I much wish some one better versed in the art of clearly laying facts and opinions before an audience (a power that I on this my first appearance cannot expect to possess) was in my place now.

The information I intend to lay before you was chiefly acquired while serving on the late Admiralty Boiler Committee, which was directed, as pointed out in their Lordships' letter of the 5th June, 1874, to visit the dockyards and principal seaports to, as far as possible, take evidence of witnesses conversant with the subject, examine into the construction and mode of working boilers both in the Royal Navy and in the mercantile marine, take into consideration the properties and qualities of materials used in their construction, and consider fully in what way surface condensation has affected their durability, and what measures are to be taken in the future for their preservation.

To carry out these comprehensive instructions it was necessary to visit not only the Royal Dockyards, but also the great seaports and manufacturing towns of the country where, although through the courtesy and goodwill of the gentlemen we met every information in their power was freely afforded us, we found that nothing definite was known on the subject, and that to render our report of any value we required, for foundation, a comprehensive and extended series of experiments, to be carried out on a small scale at first, but eventually having the results verified by the working of new and other boilers both on board sea-going vessels and on land.

Although in the course of the afternoon I have to allude to other types of boilers, I shall assume that for marine purposes the circular tubular boiler caryfng a pressure of from 50 to 200 lbs., and working surface condensation engines, is the type of the future.

As our inquiry proceeded, we saw that great differences of opinion was held by engineers not only regarding the cause of decay, but also as to the effect of surface condensation, the predominant idea being that though it had in some cases caused more rapid decay than jet condensation, yet that, with proper care, surface condensation ought not to be more injurious to boilers than the old system.

When, however, we required information as to why decay occurred, then there were still more numerous and conflicting opinions as to the causes that produced it, and consequently as to any appropri-

ate measures which should be adopted for its prevention.

The causes to which corrosion was attributed were as follows:

1. Water too pure from constant condensation.
2. Fatty acids from oils used for internal lubrication, &c
3. Quality of the iron used.
4 Particles of copper carried in by feed.
5. Galvanic action between boiler and condenser.
6. The use of copper feed-pipes.
7. Bad management of boilers.
8. Copper in solution.
9. Use of copper internal pipes.
10. Chemical action.
11. Mechanical action.
12. Softening effect of distilled water upon iron.
13. Absence of air in water repeatedly condensed.
14. Too much blowing.
15. Decomposition of water, etc., etc.

With such differences of opinion there were, as would be expected, equal differences as to the method of working, and in particular as to the time water should be retained in the boilers.

The extreme difference is shown by two of the cases brought to our notice; in one the boiler was filled at Hamburgh with the river water, and went to Callao without increasing the density beyond $\frac{1}{32}$. On the return voyage the boiler was filled with sea water at Callao, and on arrival at Hamburgh the density was scarcely $\frac{2}{32}$. The total time under steam on the two runs being 109 days, no change of water taking place at sea. In the other case, besides filling the boilers no less than five times in 38 days, the quantity of water blown out was as much as 84″ per diem, the density being from 16° to a maximum of 16°.

We found fresh water frequently used for filling boilers when starting on a voyage. Sometimes the boiler was refilled at short intervals, all the water being changed; in other cases more or less of the water was blown out during short stays in harbor, no change taking place at sea; again, the boiler being filled in harbor, the waste was made up at sea either with fresh water carried in tanks, or in the double bottom, or from the sea.

Mineral oils were commonly used for internal lubrication in preference to those of animal or vegetable origin.

I will now, in order that you may be better able to appreciate the conditions of working which either insure reasonable durability or contribute to the decay and corrosion which it is so necessary to avoid, place before you a few illustrations taken from the many cases which came under our notice, selecting for this purpose those simple ones which, when compared, will best exhibit the chief causes of general decay.

Amongst the exceptional types of boilers one on the tubulous system was examined by order, with a view to making a special report. It consisted of a series of tubes, the heat being applied outside, was always worked with fresh water, the waste, which was very small, being made up with distilled fresh water; certain of these tubes being selected by us were taken out and cut up for examination; when the connection was cut, although the boiler had not had steam up for some time, the air was heard rushing in, showing that when not in use a vacuum was maintained in them, and on being cut open, a burr, as perfect as when the tube was fitted twelve years before, was found where one of the smaller tubes was screwed into the larger one. This boiler was worked at a very high pressure, and its good condition is, I believe, attributable to the non-admission of air in this system of working.

Some Lancashire boilers at Oldham may also be instanced as examples of great durability; we saw one that had been just opened to have the usual thorough overhaul at the end of five years. On these occasions the front plate is taken off, and the whole of the interior taken out. The iron tubes were as perfect as when they left the makers, and after they had been cleaned in a lathe would be returned into store for re-issue. We saw some that were being placed in the boiler, many of them re-issues, with the bloom on as perfect as if new; and judging from what we saw, as also from what we were told, there was no reason why some of these taken out might not have been ten years at work. The water used in these boilers passes through a feed-heater, and is much contaminated by sewage; it requires to be

filtered from the amount of solid matter in it, so much so that a few years ago the smell was so offensive that clean water was substituted, but as in a short time it was found that the boilers were suffering from corrosion the use of the dirty water was re-introduced. At these works a tea made from a substance from Finland was used as a boiler fluid, but I believe that the feed-heating, combined with the use of water having therein a large amount of organic matter, was the cause of the good result.

Another case of good condition, resulting partly from the presence of sewage and organic matter in the water, was found in the boilers of boats in the port of Bristol; all showed well, and there was very little corrosion for the time that they had been at work. In several of these boats the condensers were fitted outside under the run, and in this plan there was so little air to deal with, that no air-pumps were required.

In another line of steamships occupied in a coasting trade and making short voyages, it was usual to keep the boilers full for six weeks, and to avoid blowing off during that time, when in harbor closing all valves, etc., and keeping a vacuum; this method of working resulted in a very good condition of the boilers at the time of our inspection.

The cases of rapid decay which were brought to our notice were, as may be imagined (excluding those in the Royal Navy), of less frequent occurrence than those of a contrary character. But amongst those that came before us, I will mention that when surface condensation was first re-introduced into marine engines one large steamship company had some engines fitted so that the air-pumps also did the duty of feed-pumps. The boilers were filled with fresh water, and any waste was made up with distilled sea water from a boiler set apart for that purpose. These boilers went with great rapidity; in one case being seriously pitted after from ten to eleven days' steaming; in other cases, after steaming from 8,000 to 10,000 miles, the boilers were in such a bad condition that the system of working was changed, feed-pumps being added at the same time, by which means the rapid decay was stopped, and the boilers were given an extra life. The benefit derived was attributed to the change of system, but it is more than probable that the addition of feed-pumps, and thereby avoiding the introduction of so much air, contributed in a much greater degree to this improvement.

We had it also in evidence that the most rapid corrosion, known to a gentleman of special knowledge on the subject, was not in boilers used for steam, but for boiling water used for clothes, etc., these going much more rapidly than in those fed with the same water, and used as boilers for engine purposes.

A very instructive illustration of the corrosion to which iron is liable when the action is reduced to its simplest form, was afforded in the condition of some of the steam pipes forming part of the system used for heating the Houses of Parliament. The water from which steam is raised comes from the deep well in Trafalgar Square, and while the boilers themselves are practically free from corrosion, some of the wrought iron pipes which convey the steam many hundred feet away suffer from oxidation, in some cases to such an extent as to cause perforation of the tube. So that the only conditions which are available for explaining the corrosion in this case are steam (partly condensed, of course,) and air.

In some cases the water supplied to boilers is for economical purposes passed through feed-heaters, and we always found that the corrosive action was expended upon these feed-heaters, thereby relieving the boilers of the corrosion which they would otherwise have suffered. When feed-heaters were first introduced they were made of wrought iron, but in consequence of their rapid decay it was found advisable to substitute those made of cast iron, as being less vulnerable to corrosive action.

Experimental confirmation of some of the different conditions involved in cases of durability or decay were obtained by experiments conducted at the ordinary temperature and pressure; they were on a very small scale, but will be sufficient for the present purpose. Strips of polished boiler plate from Yorkshire iron being immersed in sea water or distilled water with or without access of air:

Bottle No. 1 contained distilled water, the upper end of the strip being just

covered by the water, the mouth of the bottle was incompletely closed by a cork.

Bottle No. 2 contained distilled water, which was boiled in the bottle to expel air, a similar strip to that in No. 1 was then introduced, and the water again boiled under the air-pump at a lower temperature to insure the complete expulsion of air, some mineral oil was then poured in, and the bottle well corked and waxed over.

Bottle No. 3 contained sea-water and a strip of iron, the other conditions being exactly similar to No. 1.

Bottle No. 4 contained sea-water, and was otherwise arranged exactly as No. 2.

These bottles, with some others which I shall presently describe, remained in the Committee Room at the Admiralty for two months.

Oxidation commenced immediately in bottles 1 and 3, the water becoming turbid from the presence of oxide of iron (rust), which formed continuously until it had collected at the bottom and sides of the bottle in considerable quantity. At the end of the period, the strips were withdrawn, cleaned and weighed; they had lost respectively in grains per square foot per ten days:

No. 1, distilled water...........	8.27
No. 3, sea-water................	5.76

The strips in bottles 2 and 4, with the exception of a slight tarnish, remained as they were put in; there was no oxidation, the water being quite clear.

Now you will be in a position to understand why it is so desirable to protect boilers not only when under steam, but also when out of use, from access of air; and by comparing the known conditions under which oxidation took place, or was prevented altogether in the bottles, with the conditions in the working of boilers, examples of which I have instanced, you will readily see why there should be decay in some cases and durability in others.

We found that in some ships the remedy adopted was the substitution of iron for all the copper pipes connected with the boilers, and in one case iron was used even for the steam pipe. In another case, air was pumped into the boilers, and this remedy has been gravely recommended by officials, although not carried out by the principals.

Washing the interior of the boilers with cement was a practice of some firms and with very satisfactory results. It was, I know, tried some years ago in the Navy, but not approved of, probably because it was laid on too thick, and the use of freshly burned cement not insisted upon. In one firm the superintending engineer was in the habit of having a quantity of mineral oil introduced the last thing before closing.

A curious remedy for corrosion in land boilers common in Lancashire consisted in putting a dead pig into a boiler that showed signs of pitting, and the engineers in some few steamers used to go on shore with a sack, in which any unfortunate cats, etc., were collected for a similar purpose. A story is related that an engineer of a ship in China told the ship boatman to bring off some dogs or cats for the boilers, but the man answered him that they were worth too much money, though if a dead Chinese would do he could find plenty. The origin of this custom is not known, but the introduction of organic matter is doubtless beneficial, when used for the purpose of preventing corrosion by the oxygen contained in air brought into boilers with the feed. Among the remedies for corrosion in boilers I might mention some which in many cases are applied with useful effect, such as an alkaline solution of organic matter, which acts (especially under pressure) in a similar manner to that last alluded to in the Lancashire remedy for pitting.

A common remedy for supposed acidity of the water in boilers, or in order to neutralize the effect of fatty acids, is found in the use of soda, usually in the state of carbonate. In some of the boiler compositions or fluids, usually of a proprietary nature, alkali and organic matter are found mixed together.

Among the remedies for corrosion the use of zinc was strongly advocated by some marine engineers, while others did not attribute any real advantage to it, in some cases even discontinuing its use. The contradictory opinions as to its value were plainly due to want of knowledge of the principles involved when the electro-chemical relations of two metals immersed in sea-water had to be considered, and in the few cases where a decided advantage could be traced to the zinc there can be no doubt

that metallic continuity, which is absolutely essential to success, had been accidentally effected.

The common method of using the zinc was to suspend it by means of a hook from one of the stays, sometimes under water, sometimes in the steam space, but in a Liverpool line of steamers, in consequence of the slabs of zinc coming down before the zinc was consumed, clip hooks were adopted; on arrival in port after each run the boilers and stays were carefully cleaned, and the wasted zinc plates replaced; now to clean the boilers thoroughly the zinc had to be removed, consequently not only was any replaced zinc put into the boilers at the last moment before closing, but many of the good slabs taken down for convenience while the boiler was being cleaned were replaced when the new was put in. By this arrangement a large proportion of the zinc would be, unintentionally it may be, in metallic connection with the boiler surfaces, and in this company all the engineers declared that zinc was of great value in preventing the corrosion of their boilers.

I have now to consider the means which have been adopted for preventing corrosion in empty boilers.

This condition has in former years been one of the chief causes of decay to the boilers of ships in the Royal Navy, because iron rusts or oxidizes most rapidly when exposed in a moist state to free access of air. Until within a comparatively recent date, the treatment of an empty boiler consisted in drying it by means of bogie fires, and if a condition of absolute dryness could have been effected during the whole time in which the boiler was open, the decay would doubtless have been diminished, but considering the nature of the surfaces, and the shape of the boilers so treated, there must have been an amount of decay which is avoided by the present methods of treating boilers out of use. The precautions against decay now adopted are:

1st. What may be called the dry method consists in drying the boiler in the old way; then pans filled with well-burned lime are placed in several parts of the interior, and lastly, before closing up, a quantity of ignited charcoal or coal is introduced, in order to withdraw as much of the oxygen as possible from the air shut up in the boiler; to insure the success of this method the sea cocks must be perfectly tight.

2d. By the wet method of preservation, the boilers are filled quite full with water up to the safety valves, the water being rendered alkaline by the addition of either lime or soda.

3d. The oil process used in the case of the gunboats hauled up on the slip at Haslar; oil being run into the boiler until full, and then pressure applied and kept on for a day, is so distributed over the whole of the interior, that when run off, a film is left, which dries and protects the interior surfaces from decay; here, however, the boilers are new.

In the mercantile marine, where boilers are seldom out of use except for short intervals, chiefly during repairs, the precautions I have mentioned are unnecessary, and in this comparative freedom from exposure lies their immunity from the decay which we have been considering.

As a precaution against the accidental admission of air to the interior of boilers out of use, it is advisable to render the water alkaline either by the addition of lime or soda; and for the purpose of illustrating these conditions, strips of iron corresponding in every particular with those previously mentioned, were immersed in bottles containing—

1. Lime water, solution of caustic lime in distilled water.
2. Sea water, rendered alkaline by a limited quantity of carbonate of soda.
3. Sea water with an excess of carbonate of soda.

In these cases corrosion was entirely prevented so long as the alkaline condition was maintained, and at the end of twelve months the strips were quite bright, as when introduced.

Another series, in which there was free admission of air to sea water of different densities, showed the following losses:

	Grains.	
In sea water of $\frac{10}{32}$ densities, loss..	2.81	per square foot in ten days.
" $\frac{6}{32}$ " ..	3.13	
" $\frac{3}{32}$ " ..	6.52	
" $\frac{1}{32}$ " ..	6.79	
Fresh water from main.........	8.33	
Distilled	6.17	
Distilled from sea water........	6.38	

Those figures which represent the loss

in sea water of different densities are interesting, in so far that sea water of high density appears to possess less power of absorbing and transferring air to iron than the water containing an ordinary amount of salt.

I shall in this place only notice seven of our experiments at Devonport. Three of these consisted in working or treating boilers as we had previously proposed, viz.:

1. To wash the interior of boilers with a coating of Portland cement.

2. To cover the interior surfaces of a boiler with mineral oil.

3. To retain the same water in a boiler for as lengthened a period as possible, so long as the density did not rise beyond $\frac{6}{32}$.

4. To ascertain the protective value of different qualities of zinc.

5. To determine whether zinc lost any portion of its efficiency through the loss of connection by riveting the plates together.

6. To compare the action of the water in jet and surface condensers upon iron.

7. To illustrate the corrosive action of feed-water, and the diminished action of the same water after it had passed through the heater upon the boiler.

1. A. The interior surfaces of a land boiler were thoroughly cleaned and washed with fresh Portland cement; this boiler was inspected from time to time; the adhesion continued always perfect and gave full protection to the surfaces, no spots of oxide being visible; and however much the cement might appear to be worn off, a scratch with a knife always showed that some of the cement remained.

B. One of the old rectangular boilers in the tug "Perseverance" (surface condenser) was, after some months' wear, cleaned as far as the nature of the boilers would admit, and washed with cement; the adhesion was very good, and, although no zinc was used, there was but little sign of decay at the end of two years.

C. Several boilers in course of construction were also treated in the same manner. First, before the heating parts were put in and again afterwards—the boilers were kept open for some months in the boiler shed before the mountings were attached. There was no sign of rusting, and the cement, if rubbed with the hand, was quite dry and dusty.

2. The interior of the other boiler of "Perseverance" was painted with mineral oil. It stood the work perfectly, and, after six months' steaming, the surfaces were quite oily. A similar experiment in the "Assistance" troopship failed, but the difference of pressure and consequent temperature (the "Perseverence" carrying only 30 lbs., while the "Assistance" carried 50 lbs.) will fully account for this.

3. The "Perseverance" retained the same water in her boilers for over six months, but in consequence of a freshet in the harbor at the time she ran them up, more solid matter was introduced than usual, and, as the quantity was gradually increased, it became necessary to empty the boilers, not because the density was too high, but on account of the priming caused by the solid matter. At the commencement of this experiment the density of the water in the boiler was 9°, and at the end of six months it had only risen 24°, or about $\frac{2\frac{1}{2}}{32}$. I wish to draw special attention to this experiment, even in its limited form, because it disposes of a notion which till within a recent period was extremely prevalent, viz., that it was necessary for the welfare of a boiler to constantly change some of the water; the reasons which were assigned for this practice being various, though mostly illogical. In the days of jet condensers, the rapid increase of density was a reason sufficiently obvious; but when surface condensers were introduced the density no longer increased with the same rapidity, and yet the practice continued, though with tight condenser tubes the water returned to the boiler from the hot well should contain scarcely any solid matter.

Possibly the old custom and the general idea that it was necessary to blow off at $2\frac{1}{2}$ densities, together with the direction on many salinometers to do so at that density, may have caused a continuance of the practice, but a little consideration will show that it is a positive disadvantage; for example:

1st. Hot water is blown out and cold water substituted; this means a loss of fuel.

2d. Water is blown out which has parted with some of its sulphate of lime, and water is substituted which contains its normal quantity, thereby constantly adding to the amount of scale upon the heating surfaces; this also means a greater expenditure of fuel, and an unnecessary opening up of the boiler in order to scale it.

3d. Water is blown out which, by boiling, has been freed from air, and water is substituted containing its usual quantity of dissolved air which contributes to the decay of the boiler.

Had it not been for the accumulation of mud in the boiler of the "Perseverance" the same water might have been retained for a much longer period, or until the density had risen to double what it was when the accidental necessity occurred for emptying.

I have specially dwelt upon this point because, even at the present day there are marine engineers who tenaciously adhere to the traditions of the past, and who consequently incur all the evils which are inseparable from an unscientific method of working.

At the same dockyard the "Trusty" tug, with jet condensers, only required to change the water six times in over five months.

A tubular marine boiler working a land engine in the dockyard retained the same water for six months, and was in an excellent condition when opened, and at the end of eighteen months' work file marks were still visible.

4. The zinc slabs in the boiler of the "Trusty" were of three qualities, viz., zinc "bottoms," ordinary commercial zinc, and a third of extra good quality; the results being that the plates lost in grains per square foot per ten days:

With best zinc	2.02
" commercial	15.14
" bottoms	18.08

5. Slabs of zinc were bolted on to a bright surface of two iron bars, each being in two parts; in one case bolted together through drilled holes with turned bolts; in the other riveted in the ordinary manner. The losses per square foot in ten days were as follows:

Bolted	33.15
Riveted	36.16

6. Here by some error the piece intended to have been in condenser of "Trusty" was placed in the passage to the hot well. The losses were per square foot in ten days:

Condenser of "Perseverance"	133.67
Hot well of "Trusty"	802.07

7. Plates were placed in four positions, two in buckets plunged in the feed heater, one being filled with water from the main, another with water from the condenser, a third in feed heater fed with overflow from the two buckets, and a fourth in the boiler. The losses were per square foot in ten days:

	Grains.
The plate in bucket filled from the main, lost	25.16
" " condenser	38.37
" " feed heater	40.52
" " boiler	1.90

but the second and third of these plates were, after a considerable time had elapsed, found to have been protected with oil showing no corrosion; if this be taken into account, the loss will be—

From main	25.16
" condenser	79.87
In feed heater	84.37
" boiler	1.90

Two series of pieces cut from the same plates of iron and steel showed the following average loss during ten days:

In "Perseverance" boiler, steel	22.63
" " iron	17.92
In feed heater, steel	78.62
" iron	71.43

The former being salt and the latter fresh water.

I now proceed to describe a more extended series of experiments called in our report the Ocean Plate Experiments, and which unfortunately at the time of the dissolution of the Committee in March, 1878, were not in a sufficiently advanced state for us to do more than allude to them. The object of this series of experiments was to determine what method of practical working at sea caused the least decay, and at the same time to ascertain whether, as in the Sheerness experiments, there was a difference in the amount of corrosion suffered by different varieties of "steel" as compared with iron when subjected to the same conditions.

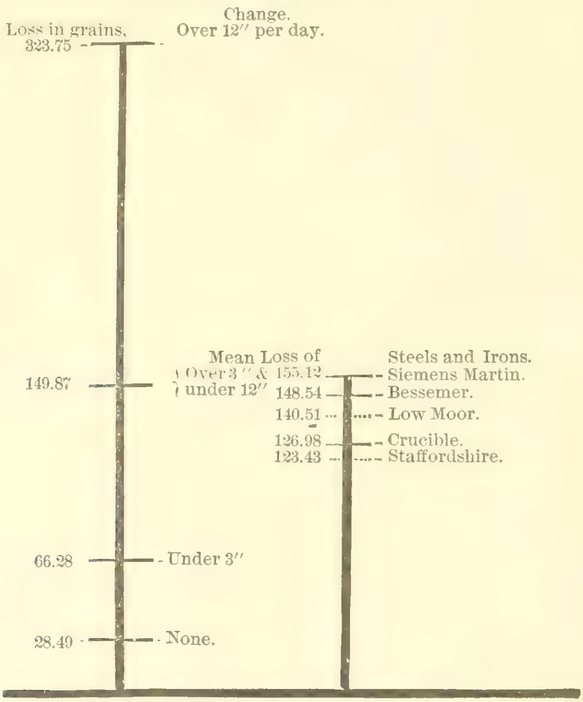
A number of sets of plates, including in each set three of steel and two of iron, were arranged in the same order, and in such a manner as not to interfere

with each other. The plates had bright but not polished surfaces, and were all of the same dimensions, viz.: 4 inches square and $\frac{3}{8}$th in. in thickness. An insulated set of these plates was suspended in such a manner as to be uninfluenced by any condition except that of the water, in one of the boilers of men-of-war on the Mediterranean, West Indian, Pacific, Australian, China, Brazil, Cape and East Indian Stations, troop ships on home and foreign service, tugs in the home ports, and merchant vessels belonging to no less than forty-five of the principal steamship companies trading to every part of the globe. A blank form was supplied with each set of plates, in order that the chief engineers might fill in all the particulars with respect to the conditions of working, and other circumstances, during the continuance of the experiment.

We anticipated that in the collective results to be obtained from so many sources, we should be in the possession of facts which would either modify or corroborate the experience which we had already acquired; and although I am sorry that I have only been able to avail myself of forty-two sets in the preparation of this paper, it very fortunately happens that amongst them there is nearly an equal number which represent the principal methods of working.

The loss is given in grains per square foot for each ten days that plates were in boiler.

OCEAN PLATE EXPERIMENTS.



The loss is given in grains per square foot for each ten days plates were in boiler.

In some few cases, however, certain sets are not available for all purposes; thus, should a boiler worked on the principle of no blowing or change of water prime badly (as in the case of the "Perseverance" before mentioned), it cannot be compared with others as to change of water, but it is still trustworthy as to the comparative corrosion of steel and iron, and also for mean corrosion.

I will first draw your attention to those results which illustrate the effects of change of water, and for this

purpose I shall divide them into four groups:

1st. Those that do not change any water at sea.

2d. Those that change 3″ and under every twenty-four hours.

3d. Those that change between 3″ and 12″ every twenty-four hours.

4th. Those that change over 12″ every twenty-four hours.

It would have been instructive to subdivide these into boilers filling with sea water and fresh water; boilers making up waste with sea water or with fresh water carried in tanks, etc.; also to distinguish between them according to the intervals of changing all or nearly all the water, but the number of results at my disposal will not permit of this.

In the 1st group of 10 sets, the mean loss was 66.49 grains per sq. foot in ten days.

In the 2d group of 9 sets, the mean loss was 26.49 grains per sq. ft. in ten days.

In the 3d group of 7 sets, the mean loss was 149.87 grains per sq. ft. in ten days.

In the 4th group of 6 sets, the mean loss was 323.75 grains per sq. ft. in ten days.

And among boilers in the first group, the plates in those which are emptied at the shortest intervals suffer most.

Now if we read these figures simply in connection with one condition of working, viz., change of waters, you will see how they confirm what I said just now with regard to its disadvantage in connection with the case of the "Perseverance," and that of boilers generally.

In what follows I have not divided the sets of plates into groups, but (except for some special purpose of illustration) include all. The effect of different lubricants in connection with corrosion is when mineral oil is compared with vegetable oil; the losses are:

Mineral......................	134.81
Vegetable....................	134.87

But though by this it would appear that the influence of lubricants has been much over-estimated, it is hardly a just view, as all the fourth group use mineral oils; excluding these, the numbers are:

Mineral oils...	74.70
Vegetable oils...............	134.87

thus showing a considerable advantage in the use of mineral oils; but it must be stated that as only four used vegetable oils, the number is too small to give trustworthy data.

We next come to the comparative merits of steel and iron so far as corrosion is concerned, and with the following results (see diagram):

Mean loss of crucible..........	126.98	Steel.
" Bessemer........	148.54	
" Siemens-Martin..	155.12	
" Staffordshire.....	123.43	iron.
" Lowmoor........	140.51	

	Of steel.	Of iron.
Group 1st, mean loss........	28.04	26.04
" 2d, " "	60.05	60.22
" 3d, " "	149.49	146.34
" 4th, " "	328.46	314.10
Mean with surface condensers,	115.67	109.44
Mean with jet condensers....	179.42	119.38

A further illustration of the effect of change of water may be given in the following results, which were obtained in connection with the first table, by comparing the use of fresh or land water with sea water:

Group 1st.....	F. 28.37	S. 20.51
" 2d......	" 48.77	" 101.70
" 3d......	" 73.28	" 166.38

This shows that while the boiler is what I consider properly worked, *i. e.*, no change taking place, the advantage is in favor of the sea water, but when the water is changed, the fresh water has the advantage. It must, however, be borne in mind that no zinc was in connection with the plates.

The advantage in using fresh water in sea-going ships will be found in the fact that by filling the boilers with it when opportunity offers at starting on a voyage, the necessity for change on account of increased density is very much diminished, if not altogether avoided.

Two sets of these plates were tested in a steamer that filled the boiler at short intervals with sea or river water, according to the port she was in, but never changed any at sea. One of these sets was suspended in the only feed heater attached to marine engines we were then aware of, the other in the boiler fed with water that had passed through the heater. The respective losses were in grains per square foot per ten days:

In boiler......................	16.53
" feed water.................	93.23

that in a steamer belonging to the same company, running between the same

ports, and worked in a similar way, being 37.44.

Considering the title of my paper, viz., "The Preservation of Boilers," I might have introduced some of the minor causes which are supposed to contribute to decay, such as the fatty acids resulting from the use of lubricants having an animal or vegetable origin; the accidental damages caused by other metals, such as copper, brass or lead;* the oxidation produced by allowing water to lie at the bottom of open boilers; mechanical and solvent action resulting in the detachment of scale or in preventing its deposit, such as the local action of the feed, and so on. Some of these causes which have been assigned for corrosion by marine engineers may contribute in a small degree to the decay of boilers, but many have nothing to do with it, and yet decay is attributed to them, instead of the real cause.

It must be remembered that a boiler is a closed vessel, to which you can admit, or from which you can exclude, what you please, with little exception, and also that what may be detrimental to an unprotected plate of iron in the open sea may be absent or comparatively harmless to the same plate when it forms part of a boiler, because the conditions as to the power to corrode and of the surface to be corroded may be totally different in the two cases.

I would not for a moment discourage all advisable precautions with regard to the mechanical safety of steam boilers, nor attempt to undervalue the inspection which doubtless has often saved many valuable lives; but the constant opening up, more especially of marine boilers, appears on reflection to be unnecessary. If it be urged that opening up is unavoidable for the purpose of scaling, then it may be answered that the accumulation of scale is preventible by a system of working which keeps it out, and it must be possible, by means of mechanical appliances, to exclude most of the dirt which gains access to a greater or less extent. So far as the scale deposited from clean sea water is concerned, there can be no hesitation in admitting that a limited amount is an advantage, not only because when well deposited it protects the boiler surfaces, but because it offers a better and rougher surface for ebullition than a smooth boiler plate. It is the practice in some ships to carry a supply of fresh water on board to make up waste. This, however, would be, for many reasons, impracticable in a man-of-war, and I will here relate, for the information of shore engineers, what happened to me while in command of Her Majesty's ship "Monarch."

We were off the south coast of Ireland, with ample coal to go anywhere, but as the ship had to try rate of sailing with other ships, I deemed it advisable to run up two of the compartments in the double bottom, next to where the coal had been chiefly taken from. That same day we had to try rate of sailing, and though we had not more than 180 tons of water in the two compartments, which we thought were completely full, the bracket framing kept the water from close filling them, and the ship was like a log, some ships which ought to have been nowhere, beating us. We went the next day into Queenstown, and I succeeded in filling the bottom, adding about 12 tons in all; we went to sea again, and easily beat the other ships, the feeling of the ship as she went through the water being quite different from what she was on the former occasion.

Under steam this evil is less felt, but men-of-war ought to be always in a state to do their best.

I will now briefly recapitulate the treatment which should be observed for boilers during construction, and the system of working which would appear best calculated to give them durability when in use for raising steam.

1. During construction the surfaces should be protected by a wash of freshly burned Portland cement, three coats being given and repeated if necessary.

2. Zinc should be distributed in such a manner that all the surfaces below the water may be equally protected, great care being taken as to metallic continuity.

3. After the proper amount of scale has been obtained upon the surfaces in the presence of zinc, there should be no blowing off, and that if practicable the waste should be made up by distilled sea water.

4. There should be a true auxiliary

*One large company has copper tube plates, and with no injury to the boilers.

boiler, not only to distil for drinking, cooking and bathing purposes, but also that, by means of a steam pipe to the condenser, it should at a low pressure make up the waste in the main boilers.

5. That the boilers should always be kept full, and steam be got up to expel the air on first filling; if likely to be soon wanted, they should then be closed with the water at the working level under a vacuum, but if not shortly required, they should be kept quite full.

6. That boilers once filled should never be opened, or air permitted to gain access, except for repair, until it is necessary to replace the zinc, the necessary time being determined by experiments, and that with a view of opening boilers as seldom as possible, whenever any zinc is changed, the whole of the zinc should be replaced.

7. That should from any cause the density rise, no change of water be made until it rises to 50°, or even 60°.

The necessary additional fittings to boilers would be a pipe from the lower part of the safety valve to condenser, so as to avoid the waste of steam, and a provision for free egress of air provided for, between the feed pump and the boiler.

"THE RIVER NILE."

By BENJAMIN BAKER, M. Inst. C. E.

From Proceedings of the Institution of Civil Engineers.

This paper may be considered as supplementary to, and where conflicting as in substitution of, the article on the same subject in Mr. Beardmore's "Manual of Hydrology." It is based chiefly upon Egyptian Government documents, the returns of Mr. Fowler's assistant engineers in Egypt, and the Author's own observations.

The height of low Nile above the mean sea level at Alexandria has been ascertained by leveling at the following places:

	Height in Feet.	Distance in Miles.
Rosetta Mouth	..*	..
Kafr-el-Zaiat	4.3	36
Grand Barrage	33.5	110
Cairo	39.5	126
Benisouef	75	200
Minieh	107	285
Siout	146	380
"First Cataract" (below)	303	714
" " (above)	319	716
Wady Halfa	392	964
Hannek	659	1,205
Guerendid	745	1,418
Oum Deras	907	1,468
El Kab	935	1,490
Junction of the Atbara	1,148	1,671
Shendy	1,165	1,756
Khartoum, junction with the Blue Nile	1,212	1,870

At high Nile the surface slope of the river averages about 5 inches per mile, except at the cataracts or rapids. The Grand Barrage is situated at the apex of the Delta, where the river diverges into two branches. For a distance of 30 miles below the barrage the surface slope of the western or Rosetta branch is $5\frac{1}{2}$ inches per mile; and of the eastern or Damietta branch, $4\frac{1}{2}$ inches. The latter branch is 13 miles longer than the former, and, as will be shown hereafter, by far the larger volume of water is conveyed down the shorter branch.

The "first cataract" of the Nile is situated at Assouan. Between Assouan and Wady Halfa the river is navigable, but there are fourteen more or less serious obstructions, such as rocks in the channel, and shifting sands. Between Wady Halfa and Oum Deras there are eighteen cataracts; beyond that to El Kab a continuous series of rapids, and from thence to Shendy three more cataracts, after which the Nile becomes navigable as far as Khartoum.

In the portions of the river where equilibrium is established between the velocity of the current and the stability of bed, the sectional areas, both at low and high Nile, are remarkably constant at widely distant points. Thus near Kohé, about 1,200 miles up the river, the area at low Nile is 14,000 square feet, and at high Nile, 71,000 square feet; whilst at Queremât, about 56 miles above

*The maximum known variation in the sea level is from −1.57 feet to +2.32 feet.

Cairo, the respective areas are 13,000 and 74,000 square feet; and at the barrage, 16 miles below Cairo, 12,500 and 72,000 square feet.

By far the most characteristic feature and interesting fact connected with the Nile is the singular uniformity in the date of commencement and the extent of its annual rise. The whole agricultural arrangements of the country hinge upon this, and the productions of the soil are so dependent upon the last few feet rise of the Nile, that with a rise of but 17 feet 6 inches famine is inevitable, and even of 19 feet 6 inches but too probable, whilst between 20 feet and 23 feet the supply of water is barely sufficient, though at 26 feet it is excessive. Beyond the latter height famine again threatens, because the salts in the soil are carried to the surface by the upward filtration of the river water, and the land becomes utterly unfit for cultivation until the salts have been washed away by a succeeding inundation. It must be observed that the surface of the land adjoining the river banks is about 17 feet above low water, and that it falls away from the river at the rate of about 5 inches per mile. Hence, with a 28-feet rise, such as occurred in 1874, the head for filtration is at least 11 feet; and although the river banks may be kept sound by the labor of a hundred thousand men, the water readily finds its way through the porous soil, and floods the land with a noxious solution of calcareous and magnesian salts and alkaline chlorides.

The height of the Nile has been recorded at Rhoda from time immemorial; but unfortunately the coudees of the nilometer are not all of the same length, so the returns have often misled European engineers. The last few feet rise of the flood are obviously of far greater importance than the first, and this fact finds expression at Rhoda by the coudees gradually becoming shorter. As the height of the high Nile is not infrequently given in the *Times*, as in the Egyptian newspapers, in coudees, or pics, and kerats (of which there are 24 to the coudee), it may be useful to state that the following equation expresses approximately the corresponding height in feet above low water:

Height in feet =1.52. (Height in coudees — 7 coudees 11 kerats.)

The Egyptian Government engineers have translated into French Arabic measurements of the high Nile occurring between 1825 and 1874, and the following are the results in feet:

1825–34	19.0	23.0	22.0	21.0	25.0	21.8	22.2	21.4	18.8	23.8
1835–44	19.4	20.4	19.0	21.0	22.0	25.2	25.0	25.2	22.0	21.6
1845–54	20.8	24.8	23.3	25.3	25.3	21.2	25.5	20.8	25.5	24.8
1855–64	20.3	25.5	21.3	21.0	20.8	25.2	26.2	23.2	26.6	19.6
1865–74	23.1	27.4	21.2	19.3	27.6	26.1	24.2	25.2	20.6	28.0

The earliest day on which the Nile commenced to rise in any of the preceding years was on the 10th of June, 1852, and the latest on the 10th of July, 1859. The earliest high Nile occurred on the 27th of August, 1868, and the latest on the 20th of October, 1872.

For some years past the daily height of the Nile has been recorded at the barrage, on a nilometer graduated to meters—a much more convenient unit than the varying coudee. The author has plotted diagrams of the heights for a series of years, and selects those for the years 1868, 1869, and 1870 as the most characteristic and interesting. To fully appreciate the identity of the phenomena exhibited each year—the first rapid rise, the slight halt, the final rise, and the relatively slow ebb to low Nile level, it is necessary to plot the diagrams on a large scale, and the original readings are therefore given to enable this to be done. As the unit of measurement and the calendar are immaterial, the author, to avoid errors in reduction, retains the metric measures and the Coptic calendar, remarking merely that the Coptic year consists of twelve months of thirty days, and a complementary month of five days, and that the first day of the year 1585 corresponds to the 11th September, 1868.

Heights of the Nile in Meters, on the Barrage Nilometer, from the Low Nile of 1868 to the Low Nile of 1871.

Coptic Year 1584.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Baouna	..	..	..	..	..	..	..	..	..	..	0.59	0.60	0.60	0.60	0.64
Ahbeeb	0.66	0.73	0.81	0.92	1.32	1.42	1.58	1.55	1.79	2.00	2.40	2.50	2.75	2.93	3.10
Missra	3.48	3.94	4.24	4.24	4.24	4.24	4.75	5.65	5.73	5.70	5.83	5.89	5.75	5.70	5.75
Nasi	5.75	5.63	5.58	..	..	..	..	..	..	..	..	..	..	..	..

Coptic Year 1585.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	5.56	5.52	5.48	5.48	5.48	5.48	5.58	5.55	5.55	5.52	5.50	5.48	5.40	5.35	5.33
Baba	5.30	5.15	5.05	4.95	4.90	4.79	4.75	4.70	4.60	4.38	4.28	4.24	4.20	4.12	4.05
Hatour	3.95	3.87	3.80	3.70	3.68	3.65	3.62	3.50	3.35	3.30	3.23	3.18	3.15	3.08	3.04
Kyak	3.00	2.90	2.85	2.80	2.78	2.75	2.72	2.70	2.68	2.65	2.60	2.56	2.52	2.50	2.48
Touba	2.45	2.40	2.30	2.22	2.20	2.15	2.07	2.00	1.95	1.85	1.75	1.70	1.60	1.12	1.10
Emshir	1.10	1.10	1.10	1.10	1.09	1.05	1.00	0.98	0.95	0.93	1.40	1.38	1.35	1.32	1.30
Barmahat	1.28	1.25	0.80	0.80	0.78	0.78	0.76	0.75	0.74	0.74	0.72	0.71	0.70	0.70	0.69
Barmouda	0.68	0.68	0.67	0.66	0.66	0.65	0.62	0.60	0.59	0.57	0.56	0.55	0.55	0.54	0.53
Bashams	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.45	0.45	0.45	0.44	0.44	0.42	0.47
Baouna	0.44	0.44	0.44	0.42	0.42	0.40	0.52	0.55	0.55	0.55	0.38	0.45	1.23	1.45	1.60
Ahbeeb	1.85	2.15	2.25	2.25	2.25	2.25	2.29	2.35	2.45	2.57	2.63	2.66	3.08	3.65	4.08
Missra	4.43	4.68	4.89	5.16	5.35	5.49	5.67	5.82	5.90	5.97	6.02	6.15	6.20	6.25	6.27
Nasi	6.35	6.40	6.47	..	..	..	..	..	..	..	..	..	..	..	..

Coptic Year 1586.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	6.50	6.60	6.65	6.75	6.85	6.98	7.00	7.02	7.05	7.07	7.05	7.10	7.20	7.30	7.40
Baba	7.74	7.92	7.95	7.75	7.60	7.50	7.40	7.29	7.20	7.09	7.00	6.90	6.75	6.60	6.40
Hatour	6.30	6.15	6.05	5.90	5.85	5.45	5.40	5.58	5.55	5.53	5.50	5.40	5.35	5.25	5.22
Kyak	5.10	5.03	4.90	4.83	4.72	4.62	4.50	4.37	4.25	4.13	4.00	3.90	3.82	3.80	3.80
Touba	3.75	3.73	3.79	3.67	3.65	3.63	3.60	3.58	3.57	3.55	3.51	3.47	3.40	3.30	3.15
Emshir	3.09	3.09	3.05	3.00	3.00	2.85	2.85	2.80	2.78	2.76	2.75	2.65	2.60	2.57	2.53
Barmahat	2.50	2.47	2.45	2.40	2.37	2.35	2.30	2.25	2.17	2.10	2.02	1.95	1.86	1.72	1.60
Barmouda	1.52	1.40	1.40	1.38	1.35	1.33	1.33	1.30	1.25	1.25	1.23	1.22	1.21	1.20	1.18
Bashams	1.17	1.16	1.15	1.13	1.10	0.70	0.70	0.69	0.68	0.65	0.65	0.63	0.62	0.62	0.60
Baouna	0.58	0.57	0.56	0.55	0.55	0.54	0.53	0.53	0.52	0.50	0.51	0.52	0.54	0.55	0.55
Ahbeeb	0.55	0.62	0.75	1.00	1.60	1.75	2.15	2.50	2.75	3.25	3 88	4.15	4.25	4.39	4.75
Missra	5.42	5.90	6.20	6.32	6.40	6.40	6.40	6.50	6.50	6.50	6.60	6.62	6.65	6.68	6.75
Nasi	6.80	6.80	6.82	..	..	..	..	..	..	..	..	..	..	..	..

Coptic Year 1587.

Months.	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
Tout	6.88	6.95	7.10	7.25	7.25	7.31	7.32	7.30	7.25	7.23	7.23	7.25	7.25	7.30	7.37
Baba	7.45	7.53	7.55	7.48	7.43	7.40	7.41	7.42	7.33	7.27	7.17	7.09	7.00	6.85	6.85
Hatour	6.70	6.55	6.30	6.13	6.05	5.95	5.75	5.75	5.55	5.40	5.38	5.25	5.25	5.15	5.12
Kyak	5.10	5.05	4.85	4.62	4.50	4.40	4.34	4.30	4.25	4.22	4.15	4.08	4.04	4.00	3.95
Touba	3.82	3.79	3.78	3.76	3.74	3.70	3.66	3.64	3.60	3.58	3.55	3.54	3.50	3.43	3.40
Emshir	3.35	3.34	3.32	3.29	3.26	3.20	3.16	3.14	3.12	3.09	3.05	3.00	2.95	2.91	2.88
Barmahat	2.84	2.82	2.79	2.76	2.73	2.65	2.57	2.53	2.48	2.40	2.39	2.33	2.28	2.25	2.23
Barmouda	2.23	2.21	2.21	2.19	2.18	2.16	2.14	2.13	2.10	2.07	2.05	2.02	2.00	1.97	1.95
Bashams	1.90	1.83	1.80	1.70	1.65	1.58	1.57	1.54	1.45	1.32	1.25	1.15	1.10	1.00	0.73

The barrage where the preceding observations were taken, is about 16 miles below Rhoda, so a difference may be expected and will be found in the readings of the two nilometers.

The average heights of high Nile at Rhoda and at the barrage, during a series of years, are given below:

	Meters.	Feet.		Years.
Rhoda*	6.97	=22.86	(average of 48	1824–72)
Barrage†	6.87	=22.54	(" 16	1846–61)
Barrage‡	6.91	=22.66	(" 10	1864–73)

The average heights in mèters at five-day intervals for the years 1846–61 have been tabulated by Lombardini as under:

——	5	10	15	20	25	28to31
January	2.79	2.68	2.58	2.48	2.39	2.26
February	2.18	2.07	1.96	1.83	1.72	1.65
March	1.54	1.45	1.35	1.26	1.18	1.08
April	0.99	0.94	0.87	0.81	0.74	0.69
May	0.64	0.62	0.58	0.53	0.51	0.47
June	0.44	0.48	0.48	0.48	0.66	9.76
July	0.90	1.05	1.27	1.44	2.16	3.22
August	4.15	4.87	5.57	5.76	5.87	5.97
September	6.09	6.13	6.18	6.17	6.19	6.48
October	6.60	6.55	6.51	6.37	6.21	6.22
November	5.73	4.97	4.66	4.09	4.00	3.80
December	3.61	3.42	3.25	3.19	2.97	2.90

It will be understood that the above are the average heights in a series of years, and not the heights in an average year. If it had been the latter the maximum height would have been 6.87 instead of 6.60, and the minimum 0.30 instead of 0.44, the difference being due to the overlapping of the dates of maximum and minimum heights in different years.

The system of irrigation practised in upper Egypt appreciably affects the readings on the nilometers of Rhoda and at the barrage. When the Nile has attained the height of about 3 or 4 meters, a large volume of water flows down the numerous canals having their beds at that height above low water; and when a still greater height is attained, banks are cut and the filling of the great basins of inundation causes the level of the water in the river to remain almost stationary for some days. In the same way, the drainage of these basins, after the water has stood on the land a sufficient period to deposit the fertilizing matters in suspension, causes an abnormal rise in the river.

Four measurements of the ordinary low Nile discharge at the barrage by Mr. Fowler's engineers, and by General Stone's Egyptian staff, gave the following results:

Cubic meters per second.

Low Nile discharge=355; 397; 415; 460; mean =406 cubic meters, or, say, 14,000 cubic feet per second.

Three measurements at Cairo by Linant Bey indicate the following discharges for high Niles, ranging from 7 to eight meters in height above zero:

Cubic meters per second.

High Nile discharge = 8,166; 9,469: 9,740; mean = 9,122 cubic meters, or, say, 320,000 cubic feet per second.

It has been shown that the maximum height of the Nile averages less than 7 meters, so the average maximum dis-

* 'Statistique de l'Egypte.' Cairo.

† Lombardini. 'Saggio idrologico sul Nilo.' Milan, 1865.

‡ Author's aeturns.

charge will also be less than the above. The author, after consideration of all the data, estimates the latter at 8,400 cubic meters, or say 296,000 cubic feet per second; and having reference to the preceding measurements at high and low Nile, and to measurements at intermediate levels by General Stone's staff and himself, he has deduced the following formula for the discharge of the Nile in cubic meters per second, for any height h, in meters above zero on the nilometer. As the Nile at low water is a series of pools at places, the local level of low water may vary with the same discharge, so the height h should be taken from the average readings on several nilometers.

$$Q = 200\ (h + 1)^{1.8} + 150.$$

Applying this equation to the mean heights already given, the following will be the average discharge in cubic meters per second throughout a series of years, at five-day intervals:

CUBIC METERS PER SECOND.

——	5	10	15	20	25	28to31
January....	2,351	2,237	2,136	2,037	1,950	1,828
February...	1,755	1,656	1,560	1,451	1,361	1,306
March......	1,221	1,153	1,081	1,018	963	897
April......	840	809	767	732	692	664
May.......	637	627	606	580	570	550
June.......	536	554	554	554	648	704
July.......	785	878	1,024	1,146	1,736	2,820
August....	3,972	4,986	6,074	6,386	6,570	6,740
September..	6,946	7,014	7,102	7,084	7,118	7,632
October....	7,850	7,760	7,686	7,436	7,154	7,172
November..	6,336	5,136	4,680	3,892	3,774	3,516
December...	3,280	2,952	2,856	2,786	2,542	2,458

For an average year the minimum discharge will be 400 cubic meters, and the maximum 8,400 cubic meters, the difference, as already explained, being due to the varying dates of the maximum and minimum discharge in different years.

From the above tabular statement, and from the analyses of Nile water by Dr. Letheby and Professor Wanklyn, the Author estimates the discharge per month of water and solids to average as follows:

——	Water in Millions of Cube Meters.	Solids in Suspension in Tons Weight	Solids in Solution in Tons Weight
January...	5,616	942,000	815,000
February..	3,715	468,000	546,000
March....	2,851	152,000	510,000
April.....	1,944	129,000	353,000
May......	1,598	76,500	326,000
June......	1,555	107,500	315,000
July... ..	3,744	668,000	610,000
August..	15,508	23,100,000	2,570,000
September	18,532	10,100,000	3,600,000
October...	20,045	7,600,000	3,200,000
November.	11,793	4,050,000	1,765,000
December.	7,517	2,180,000	1,025,000

In an average year, therefore, the Nile conveys to the sea 49,573,000 tons of solids in suspension; 15,635,000 tons of solids in solution, and 94,418,000,000 cubic meters, or, say, tons of water. Lombardini estimated the latter at 107,828,-558,000 cubic meters, but his data were imperfect.

The solids in the preceding estimate are of course assumed to be chemically dry, or the weight would be much greater. Thus, at the Cairo water works, it is found that at high Nile the solid matters deposited on the filters in the form of sludge are practically 800 parts per 100,000 of water, though Dr. Letheby's analysis indicates a maximum of 150 parts of chemically dry solids.

Large though these volumes be they would be exceeded if the measurements were taken higher up the river. Linant Bey measured the flow at Khartoum, where the White and Blue Nile join, and found the minimum and maximum flow for the year to be 297 cubic meters, and 6,044 cubic meters, in the instance of the former; and 159 cubic meters, and 6,247 cubic meters, in that of the latter. He measured also a high Nile discharge of 12,700 cubic meters at Gibil Cilcilly, near the first Cataract.* No doubt 20 or 30 per cent. of the volume of the Nile is lost between Khartoum and the barrage by evaporation and absorption.

It was stated at the commencement of this paper that by far the larger volume of water is conveyed to the sea by the Rosetta branch. This was not always so, but is a consequence of the construction of the barrage, and of the neglect

*Travaux éxécuté en Egypt. Paris, 1873.

of ordinary precautions in training the river immediately above that work. Unless matters are managed better in the future the river will take charge of affairs itself, and sweep the Rosetta half of the barrage down stream.

The Rosetta barrage is 1,525 feet in total length, and includes sixty-one arches of 16 feet 4 inches span each. The Damietta barrage is 1,787 feet long, and has ten more arches in the water-way. At low Nile, in 1874, about 200 cubic meters per second flowed through the former, and 181 cubic meters through the latter span. A few days later the volumes had increased to 305 and 268 cubic meters, and the differences then rapidly grew wider.

In September, 1877, the Author measured the flow down the two branches of the river, and the canals having their headworks at the barrage, as follows:

	Cubic Meters.	Mean Velocity of Current.
Rosetta branch..	3,220	3.28 miles an hour.
Damietta..	1,830	1.56 " "
Menoufich canal.	230	
Behera " .	140	
Total	5,420 cubic meters per sec.	

The high Nile of 1877 was one of the lowest and most disastrous for many years. At the time of the above measurement the nilometer above the barrage indicated a height of 5.25 meters, and that below, 5.10 meters. By the formula $Q = 200\ (h + 1)^{1.8} + 150$, the volume corresponding to the former height is 5,564 cubic meters, and to the latter 5,332, the mean being 5,448, or practically the same as the measured amount.

The preceding figures, significant though they are, do not indicate the worst feature about the barrage works, namely, that the 1,830 cubic meters do not approach the Damietta barrage fair and square, but are directed to it at great velocity through a narrow and deep channel at right angles to the axis of the river, and in line, therefore, with the already unstable foundations of the barrage. Thousands of tons of stone have been thrown into the cross channel, but the depth is still about 54 feet below low water, or 36 feet below the foundations of the barrage. Borings to a depth of 100 feet show that the soil is light stuff which melts almost like sugar when in contact with water; so the present critical state of affairs requires no further demonstration.

The analysis of Nile water made for Mr. Fowler by Dr. Letheby is appended. (See next page.)

The late Dr. Letheby remarks with reference to the preceding analysis:

"The amounts of solid matter dissolved in the water range from 13.614 to 20.471 parts for 100,000 of water. The former proportion was found in the December sample, and the latter in the sample taken the month of May. It appears also that the quantity of dissolved matters gradually arises from December to June, after which, with the exception of the month of September, it as gradually falls.

"Looking at the individual constituents of the water, it will be remarked that the nitrogenous matters, as indicated by the amounts of actual and organic ammonia, as well as by the proportions of organic matter, are considerable; for in the former case the total quantity of ammonia (actual and organic) is from 0.014 to 0.0271 part per 100,000 of water, and in the latter the organic matter is from 0.929 to 3.129 parts per 100,000 of water. These proportions are largely in excess of the quantities ordinarily found in the rivers of Europe.

"The salts of lime and magnesia which are present in sulphates and carbonates are not excessive, and therefore the water is well suited for domestic purposes.

"The proportions of soda in the form of chloride are also small; but those of potash, in the state of corbonate and silicate, are rather large. This is especially the case in the samples of water taken in June, September and October, when the soluble constituents of the water have the highest fertilizing power.

"It is, however, in the suspended matters that we are to look for the chief fertilizing ingredients of Nile water; and these are most abundant in the samples collected in August and September. In the former case they amount to 149.157 parts per 100,000 of water, and in the latter to 54.257 parts. After this the proportions gradually fall to 4.772 parts, which was the quantity found in the water taken in the month of May of the present year,

RESULTS OF ANALYSIS OF SAMPLES OF NILE WATER TAKEN DURING TWELVE CONSECUTIVE MONTHS.

Constituents per 100,000 Parts.	1874.								1875.			
	June 8.	July 10.	Aug 12	Sept. 20.	Oct. 12.	Nov. 12.	Dec. 12.	Jan. 23.	Feb. 12.	March.	April.	May 13.
Actual or saline ammonia	0.0057	0.0129	0.0043	0.0100	0.0071	0.0064	0.0049	0.0087	0.0048	0.0036	0.0035	0.0014
Ammonia from organic matter	0.0114	0.0100	0.0071	0.0071	0.0143	0.0114	0.0108	0.0143	0.0166	0.0086	0.0107	0.0118
Dissolved matters. Lime	4.167	3.992	4.422	4.260	2.309	4.304	4.264	4.468	4.057	4.631	4.763	5.178
Magnesia	1.623	1.513	1.030	0.617	0.483	1.132	0.926	1.029	0.874	0.977	0.823	1.629
Soda	1.201	0.744	0.587	0.301	0.504	0.318	0.369	0.347	0.307	0.594	0.830	1.301
Potassa	2.475	1.062	1.501	4.120	2.348	1.329	1.002	0.831	0.934	0.728	0.609	0.404
Chlorine	1.643	0.851	0.628	0.209	0.491	0.207	0.276	0.242	0.251	0.613	0.916	1.737
Sulphuric acid	2.808	2.838	1.837	1.996	1.908	1.911	1.764	1.960	1.813	2.263	2.009	2.931
Phosphoric acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Nitric acid	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
Silica, &c.	0.701	0.713	1.129	1.257	1.843	0.986	0.814	0.857	0.729	1.271	0.714	0.671
Organic matter	1.500	1.057	1.186	1.929	2.414	1 343	0.929	1.286	1.586	2.086	2.586	3.129
Carbonic acid and loss	4.182	3.616	4.281	4.754	3.557	3.427	3.270	3.451	4.120	4.651	4.936	4.091
Total on evaporation	20.300	16.386	16.601	19.443	15.857	14.957	13.614	14.471	14.671	17.814	18.186	20.471
Suspended matters:												
Organic matter.	0.829	9.114	18.414	5.914	4.586	3.686	1.943	1.914	1.086	0.686	0.514	0.943
Mineral matter	6.086	8.729	130.743	48.343	33.214	30.686	26.971	14.829	11.486	4.629	6.114	3.829
Total suspended	6.915	17.843	149.157	54.257	37.800	34.372	28.914	16.743	12.572	5.315	6.628	4.772

"It appears also that the proportions of phosphoric acid and potassa, which are the chief mineral ingredients of agricultural value in the suspended matters of Nile water, are more abundant in the August and September samples than in those obtained at any other time of the year. This will be evident from the following table, which shows the percentage composition of well dried Nile mud in the two periods referred to:

Percentage Composition of the Sedimentary Matters from Nile Water.

	Samples taken in Aug. and Sept.	Samples taken later in the year.
Organic matters	15.02	10.37
Phosphoric acid	1.78	0.57
Lime	2.06	3.18
Magnesia	1.12	0.99
Potassa	1.82	1.06
Soda	0.91	0.62
Alumina and Oxide of iron	20.92	23.55
Silica	55.09	58.22
Carbonic acid and loss	1.28	1.44
Total	100.00	100.00

"The conclusions from these results are:

"1st. That the fertility of the Nile water is due to the organic matter, and to the salts of potash and phosphoric acid dissolved and suspended in it.

"2d. That these constituents are most abundant in the water during the months of August, September and October, when the river is in flood; and that it is during the period of inundation that the sedimentary matter, or mud, deposited from the water, is most valuable as a fertalizing agent."

Professor Wanklyn read a paper* on his analysis of the monthly samples of Nile water furnished him by the Author, and drew attention to the remarkable alteration in the proportion of chlorine, and the constancy of the hardness. His explanation of this is that storm water sweeps over the surface of a country without penetrating far into the ground, and as the surface has long been denuded of salt, very little chlorine is found in the Nile at flood. When the river has fallen, the water which has soaked into the soil drains back into the Nile, not only concentrated by evaporation, but charged with chlorine extracted from extensive strata; so it is no matter for surprise that the water at low Nile contains six to eight times as much chlorine as the flood water. The hardness is due chiefly to finely divided carbonate of lime, and the slight variation in hardness is due, according to Professor Wanklyn, to the varying amount of carbonic acid present in the river.

Well water is necessarily more heavily charged with salts than the Nile at the worst. This is clearly evidenced by the following abstract of the analysis of the water in some wells near Cairo, and in the river:

	Well Water.	Nile Water.
Chlorine (per 100 parts)	7.28 to 25.4	0.21 to 1.74
Soda	5.13 " 10.75	0.30 " 1.30
Magnesia	2.81 " 7.91	0.48 " 1.62

Farther south, in the region of tropical rains, well water is still more impure. In 1876 Mr. Fowler, acting on the Khedive's instructions, sent an expedition, consisting of twelve engineers, one hundred and fifty soldiers, and four hundred camels, to explore the country between Aboo-Goosi on the Nile, and El Fascher in Darfour, and samples of water were brought from all the more important wells. In one of these, about 15 feet deep, situated at Mahtoul, 37 miles from the Nile, the quantity of common salt contained in the water was no less than 73 grains per gallon, and in few others was it less than 50 grains.

Observations of the fluctuations in the level of the water in Egyptian wells afford interesting data with respect to the rate of filtration through fine sand. In 1867–68 daily records were kept of the varying level of the water in the Nile at Assouan and at Cairo, and in a well situated $1\frac{1}{4}$ miles from the river at the latter place. The following table shows the height of water in the Nile, and in the well at Cairo, in meters above the low Nile of 1867, at intervals of ten days:

* See 'Water Analysis,' 5th edition. London, 1879.

	10th.		20th.		28th to 31st.	
	Nile	Well	Nile	Well	Nile	Well
January...	2.03	2.35	1.86	2.20	1.70	2.05
February..	1.55	1.92	1.45	1.76	1.35	1.65
March.....	1.18	1.47	0.81	1.36	0.69	1.30
April......	0.62	1.18	0.56	1.05	0.45	0.87
May.......	0.40	0.68	0.28	0.57	0.14	0.42
June......	0.05	0.27	0.00	0.08	0.50	0.05
July.......	0.75	0.00	1.13	0.10	2.06	0.28
August....	3.63	0.35	4.60	0.69	5.55	1.25
September.	5.97	1.98	5.73	2.32	5.72	2.69
October....	5.37	2.91	5.27	3.21	6.09	3.47
November.	4.68	3.66	3.75	3.45	3.09	3.21
December.	2.54	3.02	2.40	2.80	2.18	2.56

Between July 11th and November 8th the water in the well was rising, and for the remainder of the year it was falling. In a certain sense, therefore, it may be said that the water flowed into the well from the river for four months, and into the river from the well for eight months.

At Assouan, 573 miles above Cairo, the rise commenced on June 6th, or about a fortnight earlier than at Cairo; and the maximum flood was 8.03 meters, compared with 6.09 meters at Cairo.

Great activity prevails at the Meudon Aëronautical School, where, says *Nature*, the French Government has established extensive works for the construction of a large number of war balloons. Each of these, 10 meters in diameter, will be made of silk, varnished by a process invented in 1794. The valve is to be made of metal, and the shape will be quite spherical. Not less than forty of them will be sent to the several French armies for the purpose of making captive or free ascents when required. Of these more than half have been already constructed. The construction of furnaces for the preparation of pure hydrogen has not begun yet. The warehouse is large enough to contain inflated balloons, which can find exit by the roof. All the men and officers—except one—belong to the corps of military engineers. The works for building directing balloons have been stopped.

A French scientist recommends the use of glycerine to prevent the formation of scale in boilers, in the proportion of 1 lb. of glycerine to every 300 or 400 lbs. of coal burned.

WHAT IS MORTAR ?

From "The Building News."

There could not be a more puzzling question put to one whose experience was limited to the building practices of the metropolis, for, within its wide extent, there are many varieties of mortar used for the purposes of construction. The word itself is of ambiguous origin, but its derivation is generally supposed to have been derived, like many other good building names and practices, from the Romans, who required that the lime used by them should be rendered thoroughly homogeneous, and its particles perfectly reduced in the "mortarium" before being used. In addition to this precaution, it was also the custom, more especially during the reign of the Emperor Augustus, that a preliminary probation of two years should take place before even the mortar was permitted to be used for building purposes. The general application of the word "mortar" may be regarded as being applied generically, for there is no absolute value attached to the term in itself, and by itself. Mortar being a compound concocted of such variable ingredients, and subject to a great variety of treatment, no specific value or estimation is possible, unless it is described as being composed of a certain quality of lime, to be mixed with a definite quantity of sand.

The best and most desirable property in a good mortar is, that the materials of which it is composed shall not only be competent to secure profitable coherency of its component parts, but also possess the quality of adhesiveness, and thus bind together the bricks or other forms in the building in which it may be used.

The Romans, dealing generally with lime derived from comparatively pure carbonates, resorted to many schemes for overcoming the tendency of limes obtained from such sources either to part too readily with their water of hydration, or

not to part with it at all. If from the first cause, the result would be a dusty, pulverized mass, and, if from the latter, a wet pasty product, both alike incompetent to secure their own coherency, or impart any benefit to the materials with which they were associated. Hence, we find in the best remains of the old Roman mortars a careful and perfect blending of the lime with the sand, and, generally, the insertion of thin porous tiles or bricks to absorb any superfluity of moisture, while, for hydraulic purposes, puzzolano and trass were used in combination with pure limes for works under, or in, water. For whatever purposes, and under all circumstances, it was a condition imposed upon all engaged in building operations that the ingredients of which the mortar was composed should be intimately mixed together.

From a full appreciation of the benefits to be derived from a careful blending of the lime and sand, the early English engineers and architects resorted to the practice of beating the mortar. Smeaton adopted that mode of preparing his Eddystone mortar for the famous lighthouse, and it is from that starting point we first begin to understand the value of the impure limestone, which had, until that time, almost been regarded as worthless for building purposes. Chemical knowledge, such as it was at that period, assisted in estimating the true value of those impurities, and Smeaton's labors, guided by such rules as he could command, clearly indicated the source from which the Lias limes more especially derived their hydraulicity or water-setting capacity. The advantage of so valuable a property enabled the engineer to construct docks, harbors, and such works fearlessly: but this discovery had even a much wider influence, for it proved that limes derived from such sources possessed the hitherto unknown faculty of cohesiveness. The importance of this valuable property secured the advantage of not only holding bricks, and such like materials, together by the force of adhesion, but it also commanded that which had not, until then, been accomplished—unless by the introduction of foreign substances—namely, the perfect cohesion of the mortar itself. Common mortars, derived from pure carbonates of lime, possessed, in a high degree, the capacity of adhesiveness; but they were unable to maintain their own coherency unless their particles were accurately separated by the introduction of sand, or other suitable mechanical agency. Hitherto, the engineer and architect were troubled by the necessity of perfectly slaking the lime before it could be profitably combined with the sand, and many ingenious practices were resorted to, by the aid of water and air, to accomplish this desirable object. The new limes, however, containing silica, alumina, &c., were difficult to slake, and the practice of grinding the lime was introduced, which not only permitted its accurate combination with the sand, but secured another advantage, inasmuch as lime so treated could be kept for a length of time when carefully packed and protected from the air. This great advantage was originally realized by Smeaton, who was enabled to use some of the lime prepared for the Eddystone Lighthouse, several years after the completion of that great building, in other engineering works in the North of England.

It would have been well for the country especially, and for the reputation of constructors, especially if the lines on which Smeaton and his contemporaries worked had received more attention and consideration at the hands of their successors. The beginning of this century, however, owing to the great increase in the prosperity of the country, necessitated the erection of extensive works in canals and docks, involving the employment of a new element in construction, in the shape of the contractor. This new system relieved the engineer of much of his proper duties, and, at the same time, practically deprived him of the onus of carrying on the works, and certainly took out of his hands the personal accurate conduct and control of the details of their execution, for the success and efficiency of which he was primarily responsible. The decadence of materials and quality of work may be said to date from this time, not altogether from the apathy of the engineering control, but because works were undertaken beyond the means which could be commanded for their completion. The contractor, therefore, became master of the situation, and continued, in many cases, the progress of the works

at his own risk, and with his own means; and, under such circumstances, the quality of the work could not be very efficiently controlled, or even challenged, by the engineer. To show what evil results sprang from such contractors' work, we will mention a striking instance in connection with one of the earliest metropolitan lines, which was finished, and, indeed, almost entirely made, by a well-known contractor. After holding the line of railway in pawn for some years, until he was paid for the work he had done, he at last transferred it to the company, who not only prospered, but, in course of time, the line, which was entirely on brick arches, required widening, the execution of which was let to another well-known and more modern extensive contractor. In the course of the progress of the work, the engineer in charge complained of the bad quality of the brickwork; but the contractor, pointing to the old work, said, "Mine is better than that"; to which he received for answer—"The contractor who did that work *paid himself*, but I have the money ready to pay you, and I must insist, therefore, on its quality being unexceptional." This ancedote is given to show that the necessity for continuing work, in the absence of legitimate funds to pay for it, led to a practical abandonment of the proper engineering control. This was the period, however, when work was being done in an improper manner, and may be regarded as the beginning of the demoralization of the workman, who became the tool of the rapacious middleman, who, in his rapid race for wealth, became heedless of the quality of his work, so long as it was profitable. The legacy of this recklessness was to modern builders a most damaging one; for it resulted, as we hope to show in this discussion of the mortar question, in the present lamentable disregard of the quality of building materials in general, and the lime and sand in particular. It was at or about this period that the advent of the mortar-mill took place, which practically added to the opportunities of disguising the quality of the mortar, while it professed to add to its value. The sub-letting of brickwork—the materials being supplied by the contractor—by the rod or yard, completed the debasement of the work so carelessly controlled; the selected workman, who in his turn became a sub-contractor, disregarded thickness of joints, quality of brick or mortar, so long as he could speedily *throw* it together, and raising the biggest heap in the shortest time, was his first and indeed only study.

The primary duty required of mortar, whatever may be its quality, is to connect together bricks or stones, and the amount of it used for that purpose need not be very great. Indeed, when large blocks of stone are used, and when the required amount of accuracy is bestowed on the dress of their beds, the mortar may be simply regarded as a cushion in which is dissipated the pressure caused by the weight of the block. In ancient masonry, such as that which was employed in the building of the city of Jerusalem, the joints were so thin that with difficulty a knife could be thrust into them, and in many other ruins of antiquity the stability of the building was dependent on the faultless character of the stone dressing, without reference to the bedding joint of mortar. We had in London a few years ago, a good illustration of the effects of pressure from large blocks in the case of the bridge over Farringdon street, carrying the Holborn Viaduct. The beautiful granite columns or piers, from the Island of Mull, showed indications of fracture, and it was found, after considerable discussion and altercation among experts, that the damaging influence was due to the absence of a cushion, or interposing elastic substance between the joints, which would have dispersed and nullified the vertical thrust of the hard crystalline surfaces against each other. Sheet-lead was used, and the remedy, an easy and simple one, overcame the difficulty, and succeeded in maintaining the integrity of a structure of which the city authorities and their engineers may well be proud.

Thickness of joints, especially in brick-work, has always been a matter of discussion, and ofttimes of dispute, between architect and builder, and while the one contended for a thin joint as more becoming to the elevation of his design, the other, regardless of appearance, and limiting his vision to the profit point, made the mortar-joints as thick as the

supervising authority (sometimes, we fear, not over vigilant) would allow. Specifications prescribing that so many courses of brickwork should measure so many inches had not much deterrent influence in controlling the character of the work, and now mortar-joints may be said to be of divers thicknesses, as well as qualities. Mortar of the usual kind is not expensive, and the thick joints, while facilitating the laying of the bricks, provides a system of handling by the workmen not at all calculated to improve the appearance of the work, or add to its stability. A brick is easily laid in a soft *mess*, for the bricklayer almost throws it down, and finishes its imbedment by an artful blow from the handle of his trowel, which is followed by an equally effective stroke of the trowel-blade along the joints, completing, in a shorter time than we have taken to describe it, the laying of a brick.

Thick joints, of whatever kind of lime-mortar they may be made, are simply, from our point of view, wasteful, and, what is much worse, useless. The duty of a mortar joint, as we have already said, is to adhere the surfaces of the brick together, just as two pieces of wood are joined by the aid of glue, or other similar binding agent. In the case of wood-joining, no superfluity of glue is permissible, because the joint would be weakened if more was used than was absolutely necessary for the purpose required. The same rule is especially applicable to mortar joints, and, if possible, with more necessity for accuracy. Excess of lime, or its careless admixture with sand, renders such a mortar quite incompetent to perform the duty for which it is primarily destined. Lime obtained from chalk and other pure carbonates has no cohesive capacity, and its only useful faculty in construction is its quality of adhesiveness, and, therefore, such limes by themselves cannot, under the most favorable conditions, ever become indurated. They will either become pasty or powdery masses, according to the conditions of their surroundings. Alberti relates that he saw lime in a trench which was, from good presumptive evidence, five hundred years old, and it was then still moist as "honey or marrow." The proof of the dustiness of modern mortar is unhappily too widespread in our day to permit us to doubt of its existence; for whenever an old building is being pulled down, the dust shows that *mortar* existed only in name: even the mortar taken down with Temple Bar was merely pulverulent in character.

Various theories as to the recarbonization and silicisation of mortar prevailed in past times, leading the confiding builder to hope that, however defective his manipulation and materials were, Nature would assist in ultimately indurating the mortar. This somewhat fallacious view has received a shock at the hands of the modern chemist, who clearly demonstrates that even the mortar used in the Great Pyramids of Cheops has not even yet become perfectly recarbonated, while the mortar of Burgh Castle, Suffolk (a Roman garrison), has been shown not to have received any adventitious aid from its well-proportioned siliceous aggregates. There cannot be, or at least should not be, any comfort sought for by the builder, therefore, in that direction, and he must, if he desires to produce a good mortar, prepare it on the only legitimate lines based on a thorough scientific as well as common-sense examination of the question.

Mortar, of whatever kind, receives good or bad influences through the quality of the bricks or stones with which it is brought in contact, and, therefore, some degree of attention is required to secure the best constructive results. Differences in the porosity of bricks, for instance, have much to do with the beneficial action of the mortar, as has been shown by some experiments with Staffordshire moderately-glazed blue bricks, hard grey stocks, and soft place-bricks The two Staffordshire bricks, jointed with blue lias lime mortar, at the end of one month were separated by a force of 40lbs. per square inch, grey stocks by a pull of 36lbs. per square inch, while the soft place-bricks were pulled asunder with a force of 18lbs. per square inch. In this case the lowest result was reached through the softest material, which, doubtless owing to its excessive porosity, robbed the mortar, while setting, of its water of hydration too speedily. In another series of experiments, the lowest value was found to be from the hardest stone, the results being as

follows: Granite being equal to 11 and Portland stone 16 in relative adhesive value, the cementing agent in that case being Portland cement, so that while providing against the dangers of improper mortar, one of those not to be disregarded is the capacity of absorption in the bricks. Drenching the bricks does not, in fact, secure immunity at all times from this danger, for during exceptionally warm weather, the evaporation of the water would speedily follow, and the spongy brick would in such a case rob the mortar of its moisture.

What are the precautions required to protect buildings against the dangers common to the preparation of mortars and their use? We need not with any degree of particularity enumerate in an essay of this kind, necessarily so general in its character, the exact details, but we may briefly state that, above all things, it is essential that, of whatever proportions the mortar may be composed, accuracy of the mixture may be obtained. Proportion must always be an important factor in this question, because the quality and character of both lime and sand influence the calculations, which must, under intelligent conditions, determine on how much of one and the other should be used. Properly decarbonized lime, and all the details of its manufacture strictly perfect in character, ought to secure a matrix competent to blend with, or become incorporated with, any kind of suitable aggregate. Under any circumstances, the sand should be naturally clean, or, if foul and loamy in character, freed by washing from any impurities which could interfere with its profitable mixture with the lime. Fine sand would require a larger proportion of lime than one coarse in character, because it is a necessary condition of success in mortar-making that every particle of aggregate should be perfectly covered with lime; otherwise, the cementitious result would be defective. Fine granules increase the surfaces, and, therefore, to coat them with advantage, a more diffusive state of the lime is indispensable; otherwise, there would be vacuities, calculated to impair the coherency of the mortar, for the particles of sand, under ordinary conditions, could not be brought into sufficiently accurate contact with each other. Coarse sand is more suitable for mortar-making purposes when there is sufficient fine stuff to fill up the voids, resulting from the impossibility of forming a compact mass with such materials, and less time would be required, because there would be, in such a case, more limited surfaces to require coating from the cementing agent. The whole process, under whatever circumstances, should be mainly directed to secure well-balanced proportions, without a superfluity of either matrix or aggregate. Sands vary in texture according to the source from which they are obtained; but, generally speaking, they are composed of spherical particles, more or less hard in texture, according to the geological source from which they were originally derived. Pit-sands are not usually so favorable as those obtained from the river, or other similar sources, because they are usually associated with fine silt or loam, either contemporaneous with their original deposit or subsequently infiltrated by water action from surface sources.

Modern mortar-joints, according to our argument, are simply wasteful in their character, and, practically, exert no beneficial influence on the brickwork with which they form so conspicuous an adjunct. There is a double duty which should be forthcoming from the mortar-joints, although we fear it is never looked upon except in its single sense, that of keeping the bricks together. The other duty, that of protecting the arrises of the bricks from degradation, is a no less important one than the other, for if the mortar-joint dusts out, or is washed out by the action of the weather, the sharp angles of the bricks become rounded, and the first act of decay sets in. The Romans, famous for their attention to, and sensible knowledge of, mortar, erected buildings in many countries which still endure, when the buildings of the Middle Ages have crumbled away. Those who take the trouble to examine some of the old feudal strongholds of our own land cannot fail to see that their decay is due to the weather action of the mortar-joints, except where the concrete form of wall was adopted, and, under such circumstances, a much more durable example is apparent.

Some of our architects and engineers, without giving the question of mortar the necessary intelligent consideration,

commit the equally reprehensible practice of using too much lime in their mortar. The results of this are apparent in the unsightly discoloration of the fronts of buildings in the architectural direction, and in that of the engineering division of construction, in the numerous stalactites under the soffits of the arches of railway and other bridges. The exudence of lime in these cases is due to its having been used in excess in the mortar, and the action of water washes it out of the so-called mortar mass. There could have been no substantial coherence of the mortar under such circumstances, for the presence of *unmixed* lime was calculated to degrade, and, in the end, probably leave the sand in a state of impoverishment, at least so far as the cementing agent was concerned.

The mortar question is essentially within the control of the constructor, and we hope that these remarks will lead up to a better appreciation of a subject which has, during recent times, had but scant attention. The modern tendency to improve brickwork will doubtless result in an eventual improvement in mortar joints, for accurately laid bricks, of the bright red color of to-day, must have clearly defined joints of minimum thickness, and the pleasing surfaces must not be disfigured by the exuding lime from badly proportioned mortars.

In large works the mortar-mill takes a more prominent place than its merits deserve, and we fear that much of the bad mortar of to-day is due to the carelessness which the use of such a machine involves. While claiming the advantages of mixing lime and sand, the mortar-mill induces many malpractices, and favors the introduction into the mortar of substances ill calculated to improve its quality. Public mortar-mills are common in some towns in the North of England, where mortar can be purchased ready for use at so much a ton. Such accommodation would be most useful to the builders, were the materials of which the mortar was composed and thus manipulated true in kind and character. We fear, however, judging from the placards usually posted up in a prominent place near these mortar manufactories, that the best materials are not used, for they invite the delivery of all kinds of dry rubbish for mixing in their mortar-mill. We were sorry to find, the other day, a similar invitation at a large building in a London suburb.

To mix lime and sand thoroughly, and to secure that their quality was proper, could be beneficially done by a different kind of a machine, and the mortar, in its dry state, thus mixed, sold in sacks, ready for subsequent hydration by a careful addition of the required moisture. Mortar thus provided would be capable of easy challenge, and we think it would be less costly than the now existing clumsy and irrational preparation, surrounded as it undoubtedly is, by numerous dangers. Better reduce the extent of the joints, and use less mortar, more especially when it is evident that the present superfluity is not only wasteful, but dangerous. In the recent disaster at Finsbury Park, the thick mortar joints exerted no protective influence when the settlement of the foundations of the wall occurred; but had the mortar been composed of first-class Portland cement and good sharp sand, the wreck of a sightly building would have been more circumscribed in its extent.

When the controlling authorities, whose duty it ought to be to examine and test the quality of building materials, awaken to a sense of their position, we will no longer dread the possibility of living in houses surrounded with dangers owing to their constructive defects; for bad bricks and bad mortar would then be, as they ought now to be, regarded as simple destructives of health and comfort.

Compound Locomotives.—M. Mallet's system of compounding locomotives is, we are glad to hear, shortly to have a trial in Germany, two engines on this system having been ordered from the Schichau Works at Elbing for the Hanoverian State Railways. These locomotives are intended for local service, and have high and low pressure cylinders respectively 8.87 in. and 11.81 in. diameter, the stroke in each case being 15.75 in., and the relative volumes being thus 1:2.25. The engines have coupled wheels 44.5 in. in diameter, and the weight in working order will be 15 tons. The boilers have 5.8 sq. ft. of grate surface, and 226 sq. ft. of heating surface, and are to be worked at a pressure of 177 lbs. per square inch.

COMPARATIVE STRUCTURE OF ARTIFICIAL SLAGS AND ERUPTIVE ROCKS.

By H. C. SORBY, LL.D., F.R.S., &c.

An Address before the Geological Section of the British Association at Swansea.

In selecting a subject for an address to be given in accordance with the custom of my predecessors, I was anxious that it should be in some way or other connected with the locality in which we have met. If I had been adequately acquainted with the district, I should have thought it incumbent on me to give such an outline of the general geology of the surrounding country as would have been useful to those attending this meeting. I am, however, practically a stranger to South Wales, and must therefore leave that task to others. On reflecting on the various subjects to which I might have called your attention, it appears to me that I could select one which would be eminently appropriate in a town and district where iron and copper are smelted on so large a scale, and, as I think, also equally appropriate from a geological point of view. This subject is the comparative structure of artificial slags and erupted rocks. In making this choice I was also influenced by the fact that in my two anniversary addresses, as President of the Geological Society, I have recently treated on the structure and origin of modern and ancient stratified rocks, and I felt that, if in the present address I were to treat on certain peculiarities in the structure of igneous rocks, I should have described the leading conclusions to which I have been led by studying the microscopical structure of nearly all classes of rocks. It would, however, be impossible in the time now at disposal to treat on all the various branches of the subject. Much might be said on both the purely chemical and purely mineralogical aspects of the question; but though these must not be ignored, I propose to draw your attention mainly to another special and remarkable class of facts, which, so far as I am aware, have attracted little or no attention, and yet, as I think, would be very instructive if we could fully understand their meaning. Here, however, as in so many cases, the observed facts are clear enough, but their full significance is somewhat obscure, owing to the want of adequate experimental data, or of sufficient knowledge of general physical laws.

A considerable amount of attention has already been paid to the mineral constitution of slags, and to such peculiarities of structure as can be learned independently of thin microscopical sections. A very complete and instructive work, specially devoted to the subject, was published by von Leonhard about twenty-two years ago, just at the time when the microscope was first efficiently applied to the study of rocks. Since then, Vogelsang and others have described the microscopical structure of some slags, in connection with their study of obsidian and other allied volcanic rocks. At the date of the publication of von Leonhard's work the questions in discussion differed materially from those which should now claim attention. There was still more or less dispute respecting the nature and origin of certain rocks which have now been proved to be truly volcanic by most unequivocal evidence. I am not at all surprised at this, since, as I shall show, there is such a very great difference in their characteristic structure and that of the artificial products of igneous fusion, that but for the small portions of glass inclosed in the constituent crystals, described by me many years ago under the name of "glass-cavities," there would often be no positive proof of their igneous origin. There was also considerable doubt as to the manner in which certain minerals in volcanic rocks had been generated. The observed facts were sufficient to prove conclusively that some had been formed by sublimation, others by igneous fusion, and others deposited from more or less highly-heated water, but it was difficult or impossible to decide whether in particu-

lar cases certain minerals had been formed exclusively by one or other process, or sometimes by one and sometimes by the other, or by the combined action of water and a very high temperature. I must confess that, even now that so much may be learned by studying with high magnifying powers the internal structure of crystals, I should hesitate very much in deciding what were the exact conditions under which certain minerals have been formed. This hesitation is probably as much due to inadequate examination, and to the want of a complete study of typical specimens, both in the field and by means of the microscope, as to the unavoidable difficulties of the subject. Such doubt, however, applies more to the origin of minerals occurring in cavities than to those constituting a part of true rock masses, to which latter I shall almost exclusively refer on the present occasion. In the formation of these it appears to me that sublimation has occurred to a very limited extent. In many cases true igneous fusion has played such a leading part that the rocks may be fairly called *igneous*, but, in other cases water in some form or other has, I think, had so much influence, that we should hesitate to call them *igneous*, and the term *erupted* would be open to far less objection, since it would adequately express the manner of their occurrence, and not commit us to anything open to serious doubt.

In studying erupted rocks of different characters we see that at one extreme they are as truly igneous as any furnace product, and at the other extremity hardly, if at all, distinguishable from certain deposits met with in mineral veins, which furnish abundant evidence of the preponderating, if not exclusive, influence of water, and have very little or nothing in common with products certainly known to have been formed by the action of heat, and of heat alone. Between these extremes there is every connecting link, and in certain cases it is almost, if not quite, impossible to say whether the characteristic structure is due more to the action of heat than of water. The great question is whether the presence of a small quantity of water in the liquid or gaseous state is the true cause of very well-marked differences in structure, or whether greater pressure and the necessarily slower rate of cooling were not the more active causes, and the presence of water in one state or another was merely the result of the same cause. This is a question which ought to be solved by experiment, but I fear it would be almost impossible to perform the necessary operations in a satisfactory manner.

What I now propose to do is to describe a particular class of facts which have lately attracted my attention, and to show that the crystalline minerals in products known to have been formed by the action of heat alone have a certain very well-marked and characteristic structure, which is gradually modified as we pass through modern and more ancient volcanic to plutonic rocks, in such a manner as to show at once that they are intimately related, and yet differ, in such characteristic particulars that I think other agencies than mere heat must have had great influence in producing the final results.

In dealing with this subject I propose in the first place to describe the characteristic structure of products formed artificially under perfectly well-known conditions, and then to pass gradually to that of rocks whose origin must be inferred, and cannot be said to have been completely proved.

Crystalline Blowpipe Beads.—Some years ago I devoted a considerable amount of time to the preparation and study of crystalline blowpipe beads, my aim being to discover simple and satisfactory means for identifying small quantities of different earths and metallic oxides, when mixed with others, and I never supposed that such small objects would throw any light on the structure and origin of vast masses of natural rock. The manner in which I prepared them was as follows: A small bead of borax was so saturated with the substance under examination at a high temperature that it became opaque, either on cooling or when slowly reheated. It was again fused so as to be quite transparent, and then very slowly cooled over the flame. If properly managed, the excess of material held in solution at a high temperature slowly crystallized out, the form and character of the crystals depending on

the nature of the substance and on the presence of other substances added to the bead as test reagents. By this means I proved that in a few exceptional cases small simple solid crystals are formed. More frequently they are compound, or occur as minute needles, but the most characteristic peculiarity is the development of complex skeleton crystals of extreme beauty, built up of minute attached prisms, so as to give rise to what would be a well-developed crystal with definite external planes, if the interspaces were all filled up.

In many cases the fibers of these skeletons are parallel to three different axes perpendicular to one another, and it might be supposed that the entire skeleton was due to the growth of small needle-shaped crystals, all uniformly elongated in the line of one crystalline axis, so that the resulting mass would be optically and crystallographically complex; but in some cases the different systems of fibers or needles are inclined obliquely, and then the optical characters enable us to prove that the separate prisms are not similar to one another, but developed along different crystalline planes, so as to build up one definite crystal, mechanically complex, but optically and crystallographically simple, or merely twinned. In a few special cases there is a well-pronounced departure from this rule, and truly compound groups of prisms are formed. In the center there is a definite simple prism, but instead of this growing continuously in the same manner, so as to produce a larger prism, its ends, as it were, break up into several smaller prisms slightly inclined to the axis of the first, and these secondary prisms in like manner break up into still smaller, so as ultimately to give rise to a curious complex, brush-like growth, showing in all positions a sort of fan-shaped structure, mechanically, optically, and crystallographically complex.

I have done my best to describe these various kinds of crystals seen in blowpipe beads as clearly as can be done without occupying too much time, but feel that it is impossible to make the subject as simple as it really is without numerous illustrations. However, for the purpose now in view, it will I trust suffice to have established the fact that we may divide the crystals in blowpipe beads into the following groups, which, on the whole, are sufficiently distinct, though they necessarily pass one into the other:

1. Simple crystals.
2. Minute detached needles.
3. Fan-shaped compound groups.
4. Feathery skeleton crystals.

It must not be supposed that crystals of one or other of these groups occur promiscuously and without some definite relation to the special conditions of the case. Very much depends upon their chemical composition. Some substances yield almost exclusively those of one group, and other substances those of another, whilst in some cases a difference in the rate of cooling and other circumstances give rise to variations within certain limits; and, if it were possible to still further vary some of the conditions, these limits would probably be increased. Thus, for example, the earliest deposition of crystalline matter from the glossy solvent is sometimes in the form of simple solid prisms or needles, but later on in the process it is in the form of compound feathery tufts; and, if it were possible to cool the beads much more slowly whilst they are very hot, I am inclined to believe that some substances might be found that in the early stage of the process would yield larger and more solid crystals than those commonly met with. This supposition at all events agrees with what takes place when such salts as potassium chloride are crystallized from solution in water. Some of my blowpipe beads prove most conclusively that several perfectly distinct crystalline substances may be contemporaneously deposited from a highly-heated vitreous solvent, which is an important fact in connection with the structure of igneous rocks, since some authors have asserted that more than one mineral species cannot be formed by the slow cooling of a truly melted rock. The great advantage of studying artificial blowpipe beads is that we can so easily obtain a variety of results under conditions which are perfectly well known, and more or less completely under control.

Artificial Slags.—I now proceed to consider the structure of slags, and feel tempted to enter into the consideration

of the various minerals found in them, which are more or less perfectly identical with those characteristic of erupted rocks, but some of the most interesting, like the felspars, occur in a well-marked form only in special cases, where iron ores are smelted with fluxes, seldom if ever employed in our own country, so that my acquaintance with them is extremely small. My attention has been mainly directed to the more common products of our blast furnaces. On examining these, after having become perfectly familiar with the structure of blowpipe beads, I could see at once that they are very analogous, if not identical, in their structure. In both we have a glassy solvent, from which crystals have been deposited; only in one case this solvent was red hot melted borax, and in the other glassy, melted stone. Thus, for example, some compounds, like what I believe is Humboldtilite, crystallize out in well-marked solid crystals, like those seen occasionally in blowpipe beads, whereas others crystallize out in complex feathery skeletons, just like those so common in, and characteristic of, the beads. In both we also often see small detached needles scattered about in the glassy base. These skeleton crystals and minute needles have been described by various writers under the names *crystallites*, *belonites*, and *trichites*. Though we have not the great variety of different forms met with in the beads, and cannot so readily vary the conditions under which they are produced, yet we can at all events see clearly that their structural character depends both on their chemical constitution and on the physical conditions under which they have crystallized. None of my microscopical preparations of English slags appear to contain any species of felspar, but several contain what I believe is some variety of augite, both in the form of more or less solid prisms, and of feathery skeletons of great beauty and of much interest in connection with the next class of products to which I shall call your attention, viz: rocks artificially melted and slowly cooled.

Rocks Artificially Melted.—I have had the opportunity of preparing excellent thin microscopical sections of some of the results of the classic experiments of Sir James Hall. I have also carefully studied the product obtained by fusing and slowly cooling much larger masses of the basalt of Rowley, and have compared its structure with that of the original rocks. Both are entirely crystalline, and, as far as I can ascertain, both are mainly composed of the same minerals. Those to which I would especially call attention are a triclinic felspar and the augite. The general character of the crystals is, however, strikingly different. In the artificial product a considerable part of the augite occurs as flat, feathery plates, like those in furnace slags, which are quite absent from the natural rock, and only part occurs as simple solid crystals, analogous to those in the rock, but much smaller and less developed. The felspar is chiefly in the form of elongated, flat, twinned prisms, which, like the prisms in some blowpipe beads, commence in a more simple form and end in complex fan-shaped brushes, whereas in the natural rock they are all larger than in the artificial, and exclusively of simple characters. On the whole then, though the artificially melted and slowly cooled basalt is entirely crystalline, and has a mineral composition closely like that of the natural rock, its mechanical structure is very different, being identical with that of blowpipe beads and slags.

Volcanic Rocks.—Passing now to true natural igneous rocks, we find some like obsidian, which closely correspond with blowpipe beads, slags, and artificially melted rocks, in having a glassy base through which small crystalline needles are scattered; but the more completely crystalline volcanic rocks have, on the whole, a structure very characteristically unlike that of the artificial products. I have most carefully examined all my sections of modern and ancient volcanic rocks, but cannot find any in which the augite or magnetite is crystallized in feathery skeletons. In the case of only one single natural rock from a dyke near Beaumaris have I found the triclinic felspar arranged in just the same fan-shaped, brush-like groups, as those in similar rocks artificially melted and slowly cooled. The large solid crystals in specimens from other localities sometimes show that towards the end of their growth small flat prisms have

developed on their surface, analogous to those first deposited in the case of the artificial products. In slags composed almost exclusively of what I believe is Humboldtilite, the crystals are indeed uniformly as simple and solid as those in natural rocks, but the examination of different blowpipe beads shows that no fair comparison can be made between altogether different substances. We must compare together the minerals common to the natural and the artificial products, and we then see that, on the whole, the two classes are only just distinctly connected by certain exceptional crystals and by structural characters which, as it were, overlap enough to show that there is a passage from one type to the other. In the artificial products are a few small solid crystals of both augite and a triclinic felspar, which closely correspond to the exceptionally small crystals in the natural rocks, but the development of the great mass of the crystals is in a different direction in the two cases. In the artificial products it is in the direction of complex skeletons, which are not seen in the natural rock, but in the natural rock it is in the direction of large simple solid crystals, which are not met with in the artificial products. There is a far closer analogy in the case of partially vitreous rocks, which, independent of the true glassy base common to them and the artificial products, often contain analogous crystalline needles. Even then, however, we see that in the artificial products the crystals tend to develop into complex skeletons, but in the natural rocks into simple solid crystals.

It must not be supposed that these facts in any way lead me to think that thoroughly crystalline modern and ancient volcanic rocks were never truly fused. The simple, large, and characteristic crystals of such minerals as augite, felspar, leucite, and olivine often contain so many thoroughly well-marked glass inclosures as to prove most conclusively that when the crystals were formed they were surrounded by, and deposited from, a melted glassy base, which was caught up by them whilst it was still melted. This included glass has often remained unchanged, even when the main mass became completely crystalline, or has been greatly altered by the subsequent action of water. I contend that these glass enclosures prove that many of our British erupted rocks were of as truly igneous origin as any lava flowing from a modern volcano. The difference between the structure of such natural rocks and that of artificial slags must not, in my opinion, be attributed to the absence of true igneous fusion, but to some difference in the surrounding conditions, which was sufficient to greatly modify the final result when the fused mass became crystalline on cooling. The observed facts are clear enough, and several plausible explanations might easily be suggested, but I do not feel at all convinced that any single one would be correct. That which first suggests itself is a much slower cooling of the natural rocks than is possible in the case of the artificial products, and I must confess that this explanation seems so plausible that I should not hesitate to adopt it if certain facts could be accounted for in a satisfactory manner. Nothing could be more simple than to suppose that skeleton crystals are formed when deposition takes place in a hurried manner, and they so overgrow the supply that they develop themselves along certain lines of growth before there has been time to solidly build up what has been roughly sketched in outline. I cannot but think that this must be a true, and to some extent active, cause, even if it be inadequate to explain all the facts. What makes me hesitate to adopt it by itself is the structure of some doleritic rocks when in close contact with the strata amongst which they have been erupted. In all my specimens the effects of much more rapid cooling are perfectly well marked. The base of the rock when in close contact is sometimes so extremely fine grained that it is scarcely crystallized, and it is certainly far less crystalline and finer grained than the artificial products to which I have called attention, and yet there is no passage towards those structures which are most characteristic of slags, or at least no such passage as I should have expected if these structures depended exclusively on more rapid cooling. We might well ascribe something to the effect of mass, but one of my specimens of basalt melted and slowly cooled in a small crucible is quite as crystalline as

another specimen taken from a far larger mass, though I must confess that what difference there is in this latter is in the direction of the structure characteristic of natural rocks. The presence or absence of water appears to me a very probable explanation of some differences. When there is evidence of its presence in a liquid state during the consolidation of the rock, we can scarcely hesitate to conclude that it must have had some active influence; but in the case of true volcanic rocks the presence of liquid water is scarcely probable. That much water is present in some form or other is clearly proved by the great amount of steam given off from erupted lavas. I can scarcely believe that it exists in a liquid state except at great depths, but it may possibly be present in a combined form or as a dissolved vapor under much less pressure, and the question is, whether this water may not have considerable influence on the growth of crystals formed prior to eruption, before it was given off as steam. I do not know one single fact which can be looked upon as fairly opposed to this supposition, and it is even to some extent supported by experiment. M. Daubrée informs me that the crystals of augite formed by him at a high temperature by the action of water have the solid character of those in volcanic rocks, and not the skeleton structure of those met with in slags. The conditions under which they were formed were, however, not sufficiently like those probably present during the formation of erupted lavas to justify our looking upon the explanation I have suggested as anything more than sufficiently plausible, in the absence of more complete experimental proofs.

Granitic Rocks.—I now proceed to consider rocks of another extreme type, which for distinction we may call the granitic. On the whole they have little or nothing in common with slags or with artificial products similar to slags, being composed exclusively of solid crystals, analogous in character only to slag-crystals of very different mineral nature. As an illustration I would refer to the structure of the products formed by fusing and slowly cooling upwards of a ton of the syenite of Grooby, near Leicester. Different parts of the resulting mass differ very materially, but still there is an intimate relation between them, and a gradual passage from one to the other. The most characteristic feature of those parts which are completely crystalline is the presence of beautiful feathery skeleton crystals of magnetite, and of long flat prisms of a triclinic felspar, ending in complex, fan-shaped brushes. There are no solid crystals of felspar, hornblende, and quartz, of which the natural rock is mainly composed, to the entire exclusion of any resembling those in the melted rock. As looked upon from the point of view taken in this address, the natural and artificial products have no structural character in common, so that I think we must look for other conditions than pure igneous fusion to explain the greatly modified results. We have not to look far for evidence of a well-marked difference in surrounding circumstances. The quartz in the natural rock contains vast numbers of fluid cavities, thus proving that water was present, either in the liquid state or as a vapor so highly compressed that it afterwards condensed into an almost equal bulk of liquid. In some specimens of granite there is indeed clear proof that the water was present as a liquid, supersaturated with alkaline chlorides, like that inclosed in the cavities of some minerals met with in blocks ejected from Vesuvius, which also have to some extent what may be called a granitic structure.

In the case of one very exceptional and interesting granite, there is apparently good proof that the felspar crystallized out at a temperature above the critical point of water—that is to say, at a temperature higher than that at which water can exist as a liquid under any pressure—and it caught up highly compressed steam, comparatively, if not entirely, free from soluble salts; whereas the quartz crystallized when the temperature was so far lowered as to be below the critical point, and the water had passed into a liquid, supersaturated with alkaline chlorides, which have crystallized out as small cubes in the fluid cavities, just as in the case of minerals in some of the blocks ejected from Vesuvius.

Confining our attention, then, to extreme cases, we thus see that rocks of the granitic type differ in a most char-

acteristic manner from the products of artificial igneous fusion, both in the structure of the crystals and in containing liquid water inclosed at the time of their formation. The question then arises whether these differences were due to the presence of the liquid water, or whether its presence and the characteristic structure were not both the effects of the great pressure of superincumbent rocks. I do not see how this can be decided in a perfectly satisfactory manner, but must confess that I am inclined to believe that, whilst great pressure was necessarily the reason why the water did not escape as vapor, the presence of liquid water during final consolidation must have had very considerable influence in modifying the structure of the rock, and had a great share in developing what we may call the granitic type.

It would be very instructive to follow out the gradual passage from one extreme type to another far more completely than is possible on the present occasion. The most interesting examples of rocks, intermediate between the granitic and volcanic types, that I have been able to examine in adequate detail, are the various Cornish elvans and other quartz felsites, which furnish all but a complete passage from pitchstone to granite. Some specimens prove that quartz may crystallize out from and inclose a perfectly glassy base, without a trace of liquid water, and at the same time other specimens prove equally well that, as we approach the granitic type, the quartz was not deposited from a glassy solvent, but inclosed more or less water. In the few intermediate cases there appears to be evidence of the conjoint presence of uncombined water and melted stony matter. On the whole, if we take into consideration only the external form of the larger crystals, rocks of the granitic type are very much as though the crystals met with in truly volcanic rocks had been strained out from the glassy or fine-grained base, and the intermediate spaces filled with quartz. The internal structure of the crystals is, however, very different, the cavities in one class containing glass, and in the other water. This most essential and characteristic difference proves that rocks of the true granitic type cannot have been formed simply by the more complete crystallization of the general base of the rock. If the crystals in granite were analogous to those developed in volcanic rocks, and the only essential difference were that the residue crystallized out more slowly and completely, so as to give rise to a more coarsely crystallized base, the crystals first formed ought not, as I think, to differ so essentially as that in one case they should inclose only glass, and in the other only water. Taking all into consideration, we can therefore scarcely suppose that the crystals in granitic rocks were deposited from a truly-melted dry glassy solvent, like those in volcanic rocks or in slags.

General Results.—I have, I trust, now said enough to show that the objects here described may be conveniently separated into three well-marked groups, viz: artificial slags, volcanic rocks, and granitic rocks. My own specimens all show perfectly well-marked and characteristic structures, though they are connected in some cases by intermediate varieties. Possibly such connecting links might be more pronounced in other specimens that have not come under my notice. I must, however, base my conclusions on what I have been able to study in an adequate manner, by examining my own preparations, and leave it for others to correct any error into which I may have been led from lack of more numerous specimens. In any case the facts seem abundantly sufficient to prove that there must be some active cause for such a common, if not general, difference in the structural character of these three different types. The supposition is so simple and attractive that I feel very much tempted to suggest that this difference is due to the presence or absence of water as a gas or as a liquid. In the case of slags it is *not* present in any form. Considering how large an amount of steam is given off from erupted lavas, and that, as a rule, no fluid cavities occur in the constituent minerals, it appears to me very plausible to suppose that those structures which are specially characteristic of volcanic rocks are in great measure, if not entirely, due to the presence of *associated* or *dissolved vapor.* The fluid cavities prove that water was sometimes,

if not always, present as a *liquid* during the consolidation of granitic rocks, and we can scarcely hesitate to conclude that it must have had very considerable influence on the rock during consolidation. Still, though these three extreme types appear to be thus characterized by the absence of water, or by its presence in a state of vapor or liquid, I think we are scarcely in a position to say that this difference in the conditions is more than a plausible explanation of the differences in their structure. At the same time I do not know any facts that are opposed to this conclusion, and we should perhaps not greatly err in thus correlating the structures, even though the water was not the essential and active cause of the differences.

Confining our attention to the more important crystalline constituents which are common to the different types, we may say that the chief structural characters of the crystals are as follows:

a. Skeleton crystals.
b. Fan-shaped groups.
c. Glass cavities.
d. Simple crystals.
e. Fluid cavities.

These different structural characters are found combined in different ways in the different natural and artificial products, and for simplicity I will refer to them by means of the affixed letters.

The type of the artificial products of fusion may generally be expressed by $a+b$ or $b+c$; that is to say, it is characterized by skeleton crystals and fan-shaped groups, or by fan-shaped groups and glass cavities. In like manner, the volcanic type may be expressed occasionally by $b+c$, but generally by $c+d$, and the granitic by $d+e$. These relations will be more apparent if given in the form of a table as follows:

Slag type....	$a+b$	$b+c$		
Volcanic type....		$b+c$	$c+d$	
Granitic type..............				$d+e$

Hence it will be seen that there is a gradual passage from one type to the other by the disappearance of one character and the appearance of another, certain characters in the meanwhile remaining common, so that there is no sudden break, but an overlapping of structural characteristics. It is, I think, satisfactory to find that, when erupted rocks are examined from such a new and independent point of view, the general conclusions to which I have been led are completely in accord with those arrived at by other methods of study.

Conclusion.—And now I feel that it is time to conclude. I have necessarily been compelled to give only a general account of the subject, and perhaps for want of adequate description many facts may appear more complex than they really are. Some are, indeed, of anything but simple character, and their full explanation is, perhaps, beyond our present power. The greater part are, however, much more simple and easy to observe than to describe; and, even, if I have failed to make everything as plain as I could wish, I hope that I have succeeded in making the principal points sufficiently clear, to show that the structure of slags and analogous artificial products throws much light on the structure and origin of the various groups of erupted rocks. I feel that very much still remains to be learned, and, as I think, could be learned by the further extension of this method of inquiry. What strikes me most is the great necessity for the more complete appreciation of experimental methods of research; but to carry out the experiments necessary to clear up the essential difficulties of the subject would, I fear, be a most difficult undertaking. In the meantime, all that we can do is to compare the structure of known artificial products with that of natural rocks, and to draw the best conclusions we can from the facts, as viewed in the light of our present knowledge of chemistry and physics. My own impression is that there is still much to be learned respecting the exact conditions under which some of our commonest rocks were formed.

PUBLIC WORKS IN SPAIN.

From "The Building News."

That the public works of Spain should be insufficient, and badly regulated, seems to be a matter of course. With this people, whose deficiency in administrative ability makes their great country an unwieldy, disunited group of provinces; whose want of probity makes constitutional government a farce; and whose energy-lacking character looks upon civilization principally as so much more of luxury for those who have, or can get, money to purchase it—this state of things is only what is to be expected. Except in those localities where foreign intercourse, or a more progressive race than the average, prevails, public works tardily follow the demands of the country, rather than lead or develop its resources. There is movement—progress, I suppose it may be called—but it is a progress reluctantly yielding to the compulsion of the civilization of more energetic nations. Still it is not fair to judge Spain by simply comparison with other more highly civilized countries of Western Europe. She is not capable of the same development as are our own and some other favored lands. The extreme climates—the enervating summers and tempestuous winters—the barrenness of the flood-washed sand and rock soils, and the intractable mountainous character of a large portion of the surface in certain districts—render their being brought into a condition such as England or Belgium enjoys out of the question. It is not just, then, to estimate Spain's capability of supporting a population, or her proper proportion of roads and railways, by computation of her thousands of square miles, with such standards as these.

The roads, for example, are, from this point of view, very inadequate; yet, for the population and the purposes it has to serve, the system is tolerably good. I think the high roads are now, especially if the condition of other things be considered, very satisfactory. They are fairly well engineered; with, generally, good working gradients. The embankments, cuttings, bridges, and occasional tunnels, are kept in good order by a regular permanent staff of workmen, and the macadam surface of broken limestone or granite is also well kept. The "diligencias," which are not themselves models of utility or good management, have little to complain of as to their roads. Most of these vehicles now ply as feeders to the railways, in correspondence with the trains; with consequently a greater regard for punctuality than formerly. In some cases, too, the new lines of railway are commenced from both ends at once, and portions are opened as they are completed; with a connecting service of "diligencias," gradually shortening, and finally disappearing altogether. It is not long since the route to Granada was traversed thus; and, at present, the traffic from Oviedo to Leon, and from Leon westward to Lugo, has to use the same broken means of transport.

As new, or even growing cities, are in the interior rarities, nearly all the highway system is ancient. I did not see or hear of any altogether new high road; but improvement works are to be seen here and there. The approaches to some towns, upon the elevated sites favored by their founders, the Moors, which are subjects requiring some consideration, have been or are being improved. These ascents are sometimes so great as to involve zig-zags and detours of as much as a mile in length. Of course the improvements are such in a utilitarian, but not by any means, in the picturesque sense. At Toledo, the new road from the station, after crossing the river by the old bridge, "Alcantara" and making a circuit of the eastern end of the town, makes a zigzag (always rising) towards the Puerta del Sol. But it runs past this structure and alongside the fragment of the old road, instead of through it. And, artistically speaking, the grand old gate seems insulted by the disregard for its purpose. At Segovia similar works upon the principal approach were executed some time back. And at Zamora, Toro, and other elevated towns, a

reform in the entrance roads has been attendant upon the increased traffic, brought by the railway. At Avila the road from the direction of Segovia which passes under the walls of the town to the bridge, is now being reconstructed at different levels and gradients; and although there are no cuttings of any great depth, yet the granite rock which crops up through the thin soil necessitates a great deal of labor in wedging, blasting, &c.

I may note here the awakening to the usefulness of trees, which is evident in some places. Spain is sadly deficient, generally speaking, in this respect; partly, perhaps, because some sort of irrigation is almost always necessary. But one can see now in many situations near the large towns,lately-planted trees, which promise to greatly improve the parched dusty roads—notably, for numbers, near Burgos, where upon the waste lands, bordering on the river (which like most Spanish streams, shows a greed for space out of all proportion to its volume), there are some splendid "alamedes," or groves, which have been quite lately extended. These trees are principally varieties of the poplar species. But, in many localities, the elm flourishes well if supplied with water.

Some other important works, now in progress, are the improvement of the internal thoroughfares of all cities. In those few which are progressive, there are one or more new broad streets, either interesting the denser neighborhoods or extending the town toward a suburb. Some of these streets I mentioned in connection with House-building. But I reserved the notice that I wish to make of the extension of Barcelona, as belonging rather to the series of public works than to simple house-building.

Barcelona, the capital of Catalonia (called by Ford the Lancashire of Spain), overlooks the Mediterranean toward the east. It is extending with London-like rapidity over its valley, toward the hills, on the south and west sides. In the south, under the hill and fortress, which command the town, is arising a new bourgeoise quarter with wide rectangularly-planned streets and lofty houses. To the southwest, along the path of the Spanish railway, is a busy suburb of trade and manufactures. Westward, at a distance of a mile or more from the former boundary of the town lies the suburban town of Gracia, at the base, and on the lower slopes of breezy hills, upon which villas are arising in all directions. Gracia is now connected with Barcelona by a fine avenue "El Paseo de Gracia," and as this is a good representative of the modern Spanish favorite type of principal thoroughfare, I will describe it in detail.

It has first a broad central footwalk—the scene of the all-popular evening promenade—fully 50 ft. wide; then, on each side a good carriage roadway (which, in this instance, has the tramway along its inner edge), and beyond are the usual footways, also liberally wide. Each of these divisions is lined with rows of trees, and sometimes, as at Zaragoza, evergreen hedges are added. The effect is very agreeable. Of course, the amount of land necessary is rather extravagant, and where (as is generally the case in England) there is much cross traffic, the central footway would be too much intersected by crossings. But, for Spanish conditions, it is very suitable and good. It affords a curious contrast between the ancient and modern methods of resisting the heat of the climate. In this, foliage replaces the sheltering cornices and closely opposed walls by which the Moors and their contemporaries sought the necessary shade. And the airiness is, of course, much more salubrious. The "Rambla"—the older main thoroughfare of Barcelona—is also adorned with noticeable trees. They are splendid lofty planes, untrained and unlopped, except so far as is necessary for their proper care; and they show, I think, to great advantage over the conventional cones of foliage which are generally considered proper for town streets. A great number of the frontages on the "Paseo de Gracia" are already filled, and the remainder seem to be going fairly well.

The by-roads of Spain are simply as bad as they can be; sometimes spread over a hundred feet of ground, by the attempts of drivers to escape the mud or dust, and at others sunk deep in a cutting, formed by the repeated churnings of wheels and washings of trespassing rivulets. It is very true in Spain, the na-

tional proverb which says: "There is no short cut without labor."

The railways also are bad. One cannot even grant them the moderate approval which the high roads may claim. The country is often very difficult, calling for all the engineer's skill and ingenuity, and, as usual, in mountainous districts steep gradients, sharp curves, and long detours are necessary. Cuttings, even shallow ones, involve a large amount of blasting in the hardest rocks—granite, limestones, etc., or in treacherous soft sands, careful provision has to be made for the escape or diversion of the surface water. Embankments generally necessitate provisions of more magnitude than we are familiar with, for the stream in the traversed valley, which, although in summer almost a dry gravel-bed, is probably a powerful flood in winter and spring.

But, on the other hand, many of the Spanish railways traverse a country flat as the sea. In either circumstances, the ways and accessories are in bad condition. With very few and small exceptions they are single lines with loops at stations. Some few railways, however, have been constructed with tunnels, embankments, &c., of the necessary width for the second line of rails. The metals used are flat bottomed flanged, probably to avoid the detail labor consequent upon the use of chairs, &c. Sometimes even the hollow rail of ∩ section is used. And the road is worn and neglected till it attains almost its last stage of even comparative safety. Fortunately the maximum rate of speed is low. The stations, too, which are inconvenient and dirty, are placed at considerable distances from their towns. This appears to be, sometimes, merely an extraordinary freak, or a concession to the coach owners. Certainly it is intentional, for it is invariable, and often one passes the town quite near, and then has to return in one of the wretched little omnibuses from the distant station. There may be some better motive—the expected growth of the town, or some such unapparent reason. I hope so.

The rolling stock is also badly maintained, and often badly constructed. The engines are mostly of English or French make, and, I suppose, are good enough but are neglected. The carriages are nearly equal to the most inferior of English lines. Occasionally, of course, better specimens than this low average are met with.

The construction of new railways is, at present, I understand, principally carried on with French capital. Some of the latest sections opened are the following: Bobadilla to Grenada, Seville to Bobadilla (completing a direct route from Seville to Granada), Madrid to Talavera, and Lerida to Tarragona. Among the most important lines in progress are —from Vigo to Lugo and La Corunna; from Leon to Orense, meeting the last-named line; from Oviedo to Leon, Aranjuez to Cuenca, Seville to Huelva, and Seville to Badajoz. Parts of some of these lines are already finished and working, as before described, with connecting services of "diligencias."

There are also projects, shortly to be realized, of lines—from the present Cadiz line to the neighborhood of Gibralter, from Badajoz to Malpartida, from Vilalba (on the Madrid line) to Segovia, and a long line from Saragoza southwestward, parallel with the coast. A glance at the map will show that until these are complete the railways of Spain can hardly be called a system; and even then many large towns will only be indirectly connected by routes involving considerable detours.

Bridges are, in this country, frequent necessities. And the powerful action of nature and time enforce a certain standard of solidity and thoroughness. The greater number of the larger towns have their ancient bridges dating from the Mediæval or even the Roman epoch; well constructed originally and fairly well cared for now. Leon, Salamanca, Zamora, Toro, Valladolid, Avila, Toledo, Zaragoza, and Cordova have each one or more interesting old bridges over their respective rivers; most of them highly picturesque structures, with a fantastic variety of arches and piers and gate-houses—the result of many successive damages and repairs or partial reconstruction. That at Toro shows, too, a curious example of some of the difficulties to be contended with, in the erection and maintenance of such works. The bridge, which originally was, of course, about at right-angles with the direction of the stream, now appears, from some

points, to run parallel with it. The river has gradually changed its bed, by encroaching upon the soft soil of the left bank, necessitating the addition of more arches to the bridge; and then, again, an embankment wall of considerable length to protect the road and prevent the floods from severing the communication with the bank. And as the works are done very sparingly (it is not a rich community) the question is not decided, but only delayed. The river still persists at certain times in crossing over the road instead of under the bridge.

The new bridges occasionally seen are of similar character to those prevalent in the south of France; rounded piers with segmental arches — more useful than beautiful. But they are far better than the light, straight, ugly lattice girders which have been used at Lerida to replace part of the stone bridge recently destroyed. Two foot-bridges of similar inartistic iron construction have been thrown across the picturesque house-lined river at Gerona, sadly disfiguring the view of the stream. There are about the country a few examples of the cast-iron arch construction, which have a somewhat less offensive appearance. Not unfrequent in some less populated districts are light suspension bridges of wire, rope, and timber which have the advantages of cheapness both of material and construction, and are sufficient for their purpose.

In Madrid a miniature Holborn Valley, near the royal palace, has lately been provided with its iron viaduct, which is not, however, a work of any great magnitude.

In noticing railway bridges, I must first mention a smaller construction than what is usually termed a bridge. These are the lesser works for the occasional floods which sweep over certain plains—shallow broad sheets of water of insignificant power, perhaps—unopposed; but capable of great destruction if accumulated against such a dam as a railway embankment. Little height is necessary. The railway, elevated a few feet above the plain, is carried over a series of transverse stone piers, somewhat close together, with girders, or rather sleepers, to receive the metals. There is generally no floor. The bridges proper, by which the lines cross the large rivers, are nearly all the most simple, and similar lattice girders of rectangular outline (with the rails at the level of the bottom flanges), often of considerable span and frequently required to be much longer than the ordinary breadth of the stream, so as to accommodate exceptional states of the water. I must confess I was surprised at the lightness, almost, one might say flimsiness, of these structures, as compared with their spans and loads, and our usual notions of the relationship of these data. I have had an opportunity of learning that this economy is arranged by working out the usual formulæ with an unusually high coefficient of strength of the material. Notwithstanding this the material itself is of inferior quality, principally, I believe, Belgian. It is probable, however, that (as I noticed of timber-work in house-building) the fitting and jointing are carefully attended to, and thus the principal source of weakness, for which exorbitant "margins of safety" are usually allowed, may be to some extent curtailed. Indeed, it seems to me a question whether the generally prevalent extravagant allowance for defects is not over-reaching itself in becoming a direct encouragement to carelessness. I do not advocate exactly what I see here, the motive of which is undoubtedly economy; but still that object is attained and the trains pass and repass safely and regularly enough; possibly more so than if the engineers had known they had a big "margin for safety" to trifle with.

The piers to these bridges are of iron or stone, according to circumstances. If the former the same economy, of course, rules their proportions.

I saw in traveling in mountainous districts several examples deserving, I think, more attentive examination than the superficial one I was able to bestow upon them. The portions of lines between Burgos and Zaragoza (by Logroño) between Madrid and Avila, Alcazar and Cordova, and between Grenada and Bobadilla, I remember as being particularly interesting for their difficult engineering problems and solutions. At Madrid and Barcelona there are several lines of tramways through the main thoroughfares. They are worked with English cars, and probably owe more than this to English assistance.

Those at Barcelona are laid with a rather surprising disregard for the convenience of the non-traveling public. The lines in some cases pass along narrow streets where there is but about two feet breadth of footway, and so close to the curb that shop sunblinds, signboards, &c., are almost suppressed, and foot-passengers and inhabitants have to take refuge in doorways as the cars pass. This is more than inconvenient—it is dangerous. But it does not appear to be here considered the particularly selfish infringement of public rights which it undoubtedly would be in England. A section of the local press which protests against the whole system, probably goes too much to that extreme to gain any important influence, as the tram-cars are favorite means of transport. The lines are allowed to get into a very bad state of repair, too, but the vehicular traffic is not representative of so strong an interest as to make effectual protest against that evil.

Upon a line which runs out four or five miles northward to the suburbs in that direction, the service is worked by steam engines, which are of English make (Merryweather's, if I remember rightly). They draw trains of three cars each, upon lines laid at the edges of the road. These also are in bad order, and the high rate of speed used along the less-frequented sections of the road will probably, before long, end in an accident, and perhaps the condemnation of the whole system, when only the manner of working it is to blame. I traveled by this line, and watched the effect of the engine and cars upon the few horses we passed. I was pleased to be able to observe that only slight notice was accorded by them. It is likely that these animals had encountered the thing before, and no doubt many horses which will be alarmed at the first appearance of such a machine, will be reconciled to it more speedily than some of their masters. It appears strange that a distant and less busy land should be enjoying the benefits of our advanced science while we at home are so fettered by laws and restrained prejudices that even a trial of sufficient duration to be fair is impossible.

In harbor works the maritime towns show a desire to keep pace with the times; but I have, unfortunately, little information upon this subject. Barcelona is improving her accommodation for shipping by constructing an inner harbor, and Cadiz and Seville have a certain amount of such work in hand. But some of the other busy seaports did not come within my range.

I do not know of any late addition to the few canals of Spain. The same circumstances which I have described as making railway operations difficult have, of course, even more force against canals. The present canals, which I occasionally met with here and there, appeared to be as deserted of boats as are the rivers. But probably, later in the year, when the harvests and vintages have been got in, there is more occasion for their use. There can be no doubt that an extension of the canal system in the plains would be highly beneficial, if only for purposes of irrigation.

The rivers are distressingly neglected as far as navigation is concerned. Some of the larger ones, which are permanently well filled, are for many miles capable of being rendered navigable with only a moderate expenditure of capital and labor. Indeed, the question has long ago been discussed, and this fact admitted. And yet they are left to the dams and mills, with hardly a ferry boat upon the broad highways which ought to be arteries of commerce.

The ingenious, if not skillful, schemes of irrigation which prevail everywhere in this land of drought, deserve mention. The long sinuous channels and rough, yet carefully-regulated dams, of stones and mud have a certain set of principles and methods, the result of years of experience, which make their construction a little science. And the treatment of slopes and other difficult surfaces so as to render them amenable to this control, belongs to the same subject. But a detailed description is perhaps beyond the province of this paper.

The water supply to towns still leaves much improvement to be desired. The source is generally the river, and only in one or two instances is the filtration even tolerably effective. So that, although Spaniards drink a great deal of water, pure, or rather untempered, yet a glass of really good water is, in the lesser towns, a treat only occasionally enjoyed,

and more often the stranger drinks with dubious anticipation of the effects of the unaccustomed solution. The supply to the public fountains is fairly abundant in ordinary times, and the irksomeness of the necessary carriage is not felt as a hardship where nothing more convenient has ever been known. In seasons of drought, however, there is sometimes serious suffering arising from the scarcity or badness of water.

The lighting of towns is fairly well done, allowance being made for the absence of gas, which only the capital and a few other favored cities can boast. The lamps are fed with petroleum, and I notice an extensive and growing appreciation of this fluid for domestic as well as public purposes..

The police administration is related to rather than connected with these subjects; but I must note the interesting fact that every town (except, I think, Madrid) has still its ancient service of watchmen, who patrol the streets, armed with spear and lantern, and chant the time o'night and the state of the weather, embellishing the cry sometimes with a pious ejaculation. There is something charmingly out of date about all this.

Of buildings which deserve to rank as public works, there are, I fear, but few examples of late erection to be enumerated. The national pastime, bull-fighting, despite all the talking of its discouragement, has yet vitality enough to demand and obtain substantial new theaters. These are highly interesting structures, partly on account of the many points in which they resemble the ancient Roman amphitheater. The new "Plaza de Toros," at Madrid, is a vast open amphitheater of granite steps, encircling the arena and its ring passageway, and surmounted by the two-storied covered structure which contains the higher class of seats, and under which are the passages and corridors. The inclosing wall is in a kind of modernized Moresque style.

There are, in different towns, a few administrative buildings and theaters, barracks, &c., of no particular note. The exterior of a new theater in the "Paseo de Gracia" before mentioned (Teatro Español), deserves note for its good adaptation of Moresque architecture to modern street purposes. It has a façade in two blocks of similar and symmetrical design, with the entrance gateway and passage between them. The detail is generally very agreeable, although not quite pure. The interior of the theater itself is not particularly good or novel.

Of churches, ancient towns have inherited a sufficiency for the wants of to-day; for where progress and increase of population are active, heresy and scepticism are also rife in a more than proportionate degree—so that often fewer rather than more churches are required. Barcelona, with its 300,000 souls, has not so many churches as some old towns of 10,000.

Schools, museums and hospitals are generally accommodated in ancient buildings, either built for those purposes, or afterwards appropriated to them. In these departments of civilization there are not many signs of activity, although there is a knowledge extending that something more is wanted.

In submitting these traveler's notes to the readers of the *Building News*, I must make some apology for their short comings. I do not pretend that they are exhaustive. There are several important cities of Spain of which I saw nothing. And they are, perhaps, not altogether free from occasional error, as those things which I have noticed I have to write of inconveniently, and without even a guide-book to represent the literary aids which one generally has at command. Perhaps these circumstances may be urged against the criticism I should otherwise deserve.

ENGINEERING STRUCTURES.

Proposed Tunnel Under the English Channel.—An excursion was made a few days ago by M. Léon and M. Varroy, the Minister of Public Works, accompanied by M. Ribot, deputy, and Fernand Raoul-Duval, civil engineer, to Sangatte, near Calais, for the purpose of visiting the soundings which have been undertaken by the Submarine Tunnel Company between England and France. The excavations have been commenced at some distance from the village, at a spot where the cliffs have an altitude of 70 ft. above the level of the sea at high water. A point has been chosen where the rocks of gray chalk which have to be traversed by the tunnel come to show their heads at the surface of the soil. On the opposite shore similar borings have been, as is known, begun, so that the works are proceeding simultaneously.

The soundings that have been made during the last few years demonstrate that the base of the Channel consists of a compact mass of chalk, resting on banks of slate. This mass, which is easy enough to pierce, is said at the same time to sufficiently resist infiltration. It would, therefore, present a substance excellently adapted for perforation. But what yet remains to be proved is, whether the succession of these chalk layers will not disclose some irregularities or ruptures which would render the enterprise impossible. That is why, before commencing the definitive works, it was necessary to make an attentive study of the ground by means of trial excavations. It is now five years since the company which had obtained the concession for the tunnel began the first borings at Sangatte. But only since last year have the works been prosecuted with any activity.

The chairman of the company was originally M. Michel Chevalier, but since his decease the place of the great economist has been taken by M. Léon Say. The period allotted for the trials was not to have exceeded five years; but as, according to the terms of the concession, the Government was authorized to prolong this term by three years, the Minister of Public Works did not hesitate to accord this extension. However, before making a formal engagement, M. Varroy wished to examine for himself what had been done. The shaft has now reached a depth of nearly 200 feet, or about 130 feet below the level of high water. It has a width of 10 feet, and is lined with oak, so that the water cannot penetrate very freely—not more than 17 gallons a minute. This water is not salt, which is thought to prove that the layers hitherto traversed have their point of contact sufficiently far from the shore to prevent the sea from ascending the shaft. It is intended to sink to a depth of 300 feet, and then a gallery will be excavated in the direction of England. Up to the present the engineers are highly satisfied with the results obtained, as no irregularities have been discovered, which is considered a good augury for the success of the enterprise.

Unfortunately, with the greatest exertions on the part of the engineers, it is impossible to proceed at a quicker rate than twenty inches a day. Nevertheless, in eighteen months or two years enough progress will have been made to arrive at a perfect understanding about the possibility of the undertaking. It is stated that the work will not fail through lack of funds.

The Forth Bridge.—As we have already announced, it has been decided to abandon the construction of the Forth Bridge. This is not a matter for surprise. But the directors of the companies concerned, namely, the North British, the Great Northern, the Midland, and the North-Eastern, will now have to answer certain questions and give certain explanations to their shareholders. The history of the undertaking has yet to be written, and must be made public. Considerable sums have been already wasted over the scheme, and there is reason to believe that much money remains to be paid. So far as the facts can be ascertained, it seems that when the last design was prepared by Sir Thomas Bouch, no money could be obtained from the public to carry out the scheme, because some competent firms of bridge-building engineers would not take the contract for carrying out Sir Thomas Bouch's design, and those who were not unwilling to tender pointed out that there was no capital subscribed. Thus the matter stood in such a position that the public would not take shares because there were no contractors; and engineers would not tender, some of them because they condemned the design, and others because there was no capital subscribed. It was generally considered that the whole thing had fallen to the ground, when it was suddenly announced that Messrs. Arrol and Co. had taken the contract. Now Messrs. Arrol and Co. are a highly respectable and competent firm, but it does not appear that they had ever carried out a really large contract for bridge work, and that they should have awarded to them a contract for such an enormous bridge as that proposed by Sir Thomas Bouch caused some surprise. No one asserts—we ourselves least of all—that Messrs. Arrol could not have built the bridge if it could be built at all. But a great many men of much more experience asserted that the design was wholly impracticable, and it would in the fitness of things have been more satisfactory had some firm of great experience in the erection of large bridges undertaken the work. It is now stated that the scheme has been abandoned, but the question arises, what will Messrs. Arrol and the other contractors have to say on this subject? Rumor asserts that Messrs. Arrol will receive a sum of £20,000 by way of penalty for the failure of the company to carry out the undertaking. Whether this is true or not will be asked by the shareholders, and must be answered by the directors. Again, if the design for the bridge was quite satisfactory, and the terms of the contract all that could be desired, why is it that the scheme has not been proceeded with? The fall of the Tay Bridge has very little to do with the matter. The reason argued by the directors for the abandonment of the scheme is not convincing. In one word the whole matter requires careful investigation, and a detailed account of all the circumstances and of the progress of events should be made public.

The Trans-Russian Canal.—A correspondent of the *Newcastle Daily Chronicle*, alluding to the canals which unite the Vistula and Dneister, writes: "It may interest your readers to know that, eighteen or nineteen years ago, when Warsaw was still unsettled after the revolution of 1861, Messrs. Wigham, Richardson and Co., of Low Walker, built a small paddle steamer for service in the river Dneiper, in the neighborhood of Kieva. This little steamer was of extremely light draught; in fact she only drew 17 inches. As there was considerable difficulty about insuring such a craft, a member of the firm went with her from the Tyne, across the North Sea and the Baltic, up the river Vistula as far as Warsaw. He

left the steamer at Warsaw, and she afterwards dropped down the stream as far as the entrance of the river Bug, which she ascended and passed through the canal which is cut through that huge marsh land—the spongy reservoir whence all these great rivers flow. He found the navigation of the Vistula itself for 400 or 500 miles between Danzig and Warsaw exceedingly difficult even with an experienced pilot; and although they drew only 17 inches of water they repeatedly run aground." The writer of the letter we are quoting from adds that while he does not pretend to any special knowledge in such matters, with the exception of the rafts of timber which are floated down the stream, and the barges which convey the corn which grows on the banks of the Vistula to Danzig, he cannot conceive that any traffic could be carried on on this river, and certainly none in competition with railways. Count Zamoyski tried several steamers, but they always got snagged or stranded on the shifting sandbanks and the enterprise was a complete failure.

A large undertaking has recently been completed in Russia, in the shape of a long railway bridge over the Volga, on the Syoran and Orenberg Railway, connecting the cities of Syoran, in the government of Simbrisk, with that of Samara. The width of the river is nearly a mile, and as it is liable to the occurrence of very heavy spring floods, the piers—of which there are fourteen altogether—had to be built 100 feet above mean water level, the depth of the river being more than 50 feet. The girders, 364 feet long and 20 feet wide, were all riveted and put together on the right bank of the river, and then floated to their position. The whole cost of the bridge was 7,000,000 silver roubles, and it is worthy of mention that it was completed without any loss of life or any accident of importance.

The engineers of the St. Gothard tunnel are stated to be in a fair way to overcome the difficulty arising from the falling in of the roof in the part known as the "windy stretch." This stretch, which is 200 meters long, and situated almost directly under the plain of Andermatt, passes through strata composed alternately of gypsum and aluminous and calcareous schists, which absorb moisture like a sponge and swell on exposure to the atmosphere. It has given the contractors immense trouble, and has fallen in so often that it was seriously proposed a short time ago to allow it to collapse, and make a bend so as to avoid the "windy stretch" altogether. The expedient now adopted, which has so far been successful, is the rebuilding of the supporting masonry in rings of solid granite. The rings are each four meters long, so that in the event of any one of them giving away the others will not thereby be affected. The building is constructed slowly and with the utmost care; no imperfect stones are allowed to be used; the masonry is perfect, and the walls of extraordinary thickness—in the parts most exposed to pressure not less than ten feet. At the beginning of June only 34 metres of the "windy stretch" required to be revaulted.

The average yearly cost of maintenance of roads in France has recently been given as about 31,000,000f.—£1,240,000—for 37,000 kilometers of national roads, 20,000,000f. for 41,000 kilometers—22,940 miles—of departmental roads, and 75,000,000f. for 260,000 kilometers of parochial roads, without counting bridges or large rectifications. The cost price of materials varies considerably in different departments, according to the means of access to resistant rocks. On an average it is 6f. 70c. the cubic meter for the whole of France, but it descends to 3f. to 4f. in the mountainous regions, such as the Alps, L'Ardèche, L'Isère: and it rises to 11f., 13f., and even 14f. in the plain country, as in Seine-et-Oise, La Marne, and L'Aube. The wear is nearly proportional to the number of vehicles passing over the roads; in L'Ardèche it is about double what it is in L'Aveyron, and in L'Hérault it is about four times as much with equal quality of materials. The statistics further show that, per kilometer and per 100 draught-horses, the mean consumption of "metalling" is about 23 cubic meters annually. It is calculated by some engineers that to keep the roads in a thoroughly good condition this proportion should be increased to 28 cubic meters, with an additional expenditure of nearly 3,000,000f. As matters stand the consumption of road metal is about 1,326,000 cubic meters on the national roads. All this is bruised, and reduced to mud and dust every year by the wheels of vehicles and the hoofs of horses. Accumulated in a single heap, it would form a tower 130 meters in diameter and 100 meters in height. Equally spread over the whole surface of the national roads of France, it corresponds to an average wearing out of 9 mm. thickness.

London Bridges.—It will be a surprise to most people, remarks the *Echo*, to learn that, after paying £1,373,325 to free the toll bridges over the Thames, the Metropolitan Board of Works finds the bridges in such a condition as to require the expenditure of £640,000 to make them safe. Yet this is what transpired at the meeting of the Board last Friday. It is no answer to the cry of disappointment that is certain to arise to say that the expenditure will be spread over a number of years; it will have to be borne by the ratepayers, whether it is one year or twenty. Sir Joseph Bazalgette, the engineer, has presented an elaborate report, in which he describes the condition of the nine bridges (excluding that at Deptford), which demand the enormous expenditure we have named. Two of them—namely, Battersea and Putney—will have to be rebuilt, the former at a cost of £250,000, and the latter with the approaches costing £300,000. The case of Waterloo Bridge is the most curious. Soundings which have been made of the bed of the Thames since 1823, when the celebrated architect of the Menai Suspension Bridge, Telford, took the soundings, have established that the scour is continually deepening the bed of the river. Waterloo Bridge was built in 1814, upon a timber staging resting upon piles 20ft. long, and the masonry was carried to a depth of 5 feet below the bed of the river. The result

of the scour has been that the heads of these piles are now from 1 foot to 6 feet above the bed of the river, and are visible at low water. If the foundation between the piles should be washed out, the structure would inevitably sink. The engineer now proposes to put wrought-iron cylinders round each pier, and to fill up to the level of the foundations, so as to make a solid foundation right down to the piles. These works are estimated to cost £40,-000, and they were ordered on Friday by the Board. Vauxhall Bridge is in pretty much the same condition, and here it is proposed to convert the three central arches into one opening, and to dredge out, so as to get an adequate area of waterway, besides putting down similar caissons to those recommended for Waterloo; estimated cost £45,000. The Lambeth Bridge is decaying; from 5 feet of the cable 9lbs. weight of rust has been removed, of which about 42 per cent. was pure iron. The Albert Suspension Bridge, "if loaded on one side, will depress where loaded, and rise where not loaded." A part of Battersea Bridge overhangs as much as 9 feet, and the stumps of the piles are in a ruinous condition. Wandsworth Bridge has suffered from want of cleaning and painting. Putney Bridge, which is 151 years old, is in little better condition than Battersea, and is a serious obstruction to the navigation. Of Hammersmith Bridge it is remarked that it will become a matter for serious consideration whether wrought-iron should not be substituted for the cast-iron cross-girders under the roadway. The Board have resolved to seek Parliamentary powers for such portions of the foregoing projects as they have not power at the present to carry out, and for mending this bad bargain of the Board the ratepayers will have to pay what will be equal to a single rate of 6½d. in the pound.

IRON AND STEEL NOTES.

Cast-Steel Rails.—On the Upper Silesian railways cast-steel rails have been in use for a number of years, and for the Kattowitz district, Inspector Theune has published the statistics of rails which have broken during the last six years. There are in all 102 miles in his district, 84 miles of which are situated in open dry land, while 18 miles are in forests, constantly retaining moisture in the ground. The sleepers are of oak, the rails 5 in. high with a broad base and partly laid with the joints on the sleepers, partly with suspended joints. There were in all 329 broken rails during the six years' period of observation, and of these breakages 207 or 2.4 per mile occurred in the dry part of the line, and 122 or 6.8 per mile in the forest district. The fractures were distributed over different quarters of the year as follows:

First three months in the year		....	216
Second	"	"	28
Third	"	"	14
Fourth	"	"	71
			329

During the first year after laying the line, the number of broken rails was very small, most of the rails having in fact been down for eight or ten years before fracture, and the average age of a broken rail being 7.5 years. During this time about 23 million tons passed over the line. The rails are notched and drilled; 73 broke through the solid section, 51 through notches, and 205 through fishbolt holes, showing in but a minority of cases any old flaw or crack. The 73 cases of breaking through the full section, the compiler of these results regards as due to the unequal tension given to the rails in the rail-straightening machine. The 51 cases of fracture through notches are mainly caused by the sudden change in section, and not, Inspector Theune asserts, by the rail being injured in notching it, since in hardly any cases were old cracks discovered. Of the 207 breaks through fishbolt holes, 8 per mile occurred on solid fish joints, and only 1.36 on suspended fish joints. This is a very large percentage in favor of suspended joints, even taking into consideration that all the supported joints were older. It should be mentioned that the fish-plates were iron, and not like the rails of steel.

Purifying Fused Iron and Steel.—For the removal of phosphorus, sulphur, silicon, or other impurities from fused iron and steel, Mr. Ludwig Merlet, of Vienna, Austria, proposes to blow into the liquid metal alkalis, or carbonates of alkalis, or dolomite, or caustic lime, each separately; or a mixture of these or some of these materials, or each or mixtures of some or all of them combined with chloride of sodium, or nitrate of soda, sesquioxide or protoxide of iron, or cinders of oxidulated iron, or combined with a mixture of some or all of these materials, with or without addition of black wad or pyrolusite in a powdered state. Or, according to another mode of procedure, he mixes the liquid metals with alkalis, or carbonates of alkalis, or carbonate of lime, or caustic lime, or dolomite, each separately; or mixtures of these, or some of these, materials, or with a combination of one, or more, or all of these materials with chloride of sodium, or with nitrate of soda, or with both; and in combination or not with black wad or pyrolusite: or he mixes up the liquid metal with alkalis or carbonates of alkalis, each separately, or a mixture of them, or with a combination of one or more of them, or all of them, with chloride of sodium, or nitrate of soda, or with both, and in combination or not with black wad or pyrolusite.

The Future of the Puddling and Bessemer Processes.—The well known Austrian metallurgist, Professor Von Tunner, in concluding the report of the Austrian official commission on the Thomas-Gilchrist proeess, expresses his own views on the future of puddling as follows: "Of great importance is the fact that by the Thomas dephosphorization process, the Bessemer converter is no longer, as formerly, confined to the treatment of pig-iron free from phosphorus, but is now available for nearly every kind of pig. It is clear

that the Bessemer, will in the immediate future become the prevailing process everywhere for the production of malleable iron, as it is now for steel. The extinction of puddling works, especially all of those which are occupied with the production of weld iron, is, by the increase of the production of ingot iron by the Thomas method, imminent. The producers of weld iron may indeed still think they have some comfort in the belief that ingot iron cannot be readily welded, but the fact is that we have now excellent ingot iron, nearly as easy to weld as puddled iron, and it will in all probability not be long before the point whether ingot iron is really any more difficult to weld than puddled iron comes into question. Exactly the same occurred at the introduction of the puddling process in place of the refinery hearth. It is therefore greatly to be feared that the solitary hope of puddling forge owners will be soon disappointed. Moreover, the small measure of protection which the Thomas patent royalty extends at present to the puddling works must cease in a specified time. With the exception of some puddling furnaces and fineries in special localities it may be asserted that for the manufacture of malleable iron, especially of the highest qualities, the Siemens-Martin process alone can possibly compete with the Bessemer.

RAILWAY NOTES.

An electrical railway has been established in the Gardens of the Brussels Exhibition, and is working all day long with perfect regularity. The number of wagons is three, each of them carrying six passengers, with a velocity, it is stated, of 3 meters per second, or about 6.7 miles per hour, to a distance of 3000 meters for *3d.* The locomotive, of which the weight is 800 kilogs., carries a Gramme machine, worked by another machine, which is stationary.

Against the extensive railway project under consideration in South Africa, the reported opposition was of that sort that comes from the fact that each locality was favorable to the part of the scheme which was favorable to itself, and opposed to others. Hence an intolerable load of amendments and much controversy. It was, however, resolved that the border line should be extended from Queenstown to Aliwal North, *via* Dordrecht instead of *via* Burghersdorp, and that the line from Beaufort West should be extended *via* Victoria West to Hope Town.

The *Journal Official* gives the total length of secondary railways at work in France as 2207 kilometers, at the end of March last, or 225 kilometers more than last year. The 225 kilometers opened last year are as follows: Clermont to the Bois de Lihus, 16 kil.; Beaumont Persan to Hermes, 18 kil.; Velu-Beatincourt to Saint Quentin, 46 kil.; Lille to Valenciennes and extensions, 40 kil.; Crécy-Mortiers to La Fère, 8 kil.; chemins de la Meuse, 21 kil.; Remiremont to Cornimont, 24 kil.; Mézidon to Dives, 29 kil.; Miramas to Port-de-Bouc, 11 kil.; Marlieux to Châtillon, 12 kil.

The Jubilee of Railways in England.—It may be interesting just now to note that it was exactly fifty years ago on Wednesday since the first really grand work in the shape of an English railway was opened, and the first railway accident upon record took place. The line ran between Liverpool and Manchester, 31 miles in length, having been begun in 1826. The opening was attended by the Duke of Wellington, Sir Robert Peel, Mr. Huskisson, and other well-known public men. The famous "Rocket" engine was one of those used on the occasion, and it was this machine which caused the death of Mr. Huskisson.

Railways (Continuous Brakes).—A second return, presented to Parliament in pursuance of the Railway Returns (Continuous Brakes) Act, 1879, shows the amount and description of continuous brake power in use on passsenger trains on the railways in the United Kingdom for the six months ending June 30 last. The total amount of stock returned as fitted with continuous brakes to June 30, 1880, is—of engines, 1,340, or 27 per cent., and 14,872 carriages, or 36 per cent Of the engines only 931 have the brakes applied to the wheels; and included in the number of carriages there are 652, and 1,768 other vehicles fitted only with chains or pipes and connections for connecting the brake. During the six months ending June 30, 1880, the amount of stock fitted with continuous brakes is 228 engines, or 4 per cent., and 1,587 carriages, or 4 per cent. The stock not fitted with continuous brakes numbers 3,574 engines and 26,140 carriages. The rejoinders of the several railway companies to the Board of Trade circular with regard to the adoption of continuous brakes have also been issued. The manager of the London and North-Western states that his directors would not have been justified in the earlier adoption of any system of brake without considerable experience of its use, but they now believe that the brake they have decided to adopt complies with the requisite conditions, and no time will be lost in extending its use to the whole of the carriage stock of the company. The Midland Company state that they have caused nearly all the fast passenger trains to be fitted with continuous brakes which satisfy the Board of Trade requirements, but the directors do not feel justified in giving the undertaking suggested in the Board of Trade circular. The Great Northern manager argues that the immediate general adoption of any one of the forms of automatic brakes known would not attain the end the Board have in view, but ere long experience will lead to the production and use of a simple and effective brake, satisfactory to the Board and to the public, as well as to the companies. The London, Chatham, and Dover decline to commit themselves to the expense of adopting any one system, which might and probably would be immediately superseded by a better.

From the general report of the Board of Trade upon the accidents of the railways in the United Kingdom in 1879, it appears that of the total number of persons returned to the

Board of Trade as having been killed in the working of railways during the year was 1032, and the number of injured 3513. Of these, 160 persons killed and 1307 persons injured were passengers. Of the remainder, 442 killed and 1951 injured were servants of the companies or contractors; and 420 killed and 255 injured were trespassers and suicides and persons who met with accidents at level crossings or from miscellaneous causes. Of the passengers, 75 were killed (including 73 supposed to have been lost in the Tay Bridge disaster) and 602 were injured from accidents to trains. In addition to the above, the companies have returned 42 persons killed and 2314 injured from accidents which occurred on their premises, but in which the movement of vehicles on railways was not concerned. The total number of passenger journeys, exclusive of journeys by season ticket-holders, was 562,732,890 for 1879, or 2,291,565 less than in 1878. The proportions of passengers killed and injured in 1879 from all causes were, in round numbers, one in 3,517,000 killed and one in 430,000 injured. In 1878 the proportions were one in 4,520,000 killed and one in 322,000 injured. The proportions of passengers killed and injured from causes beyond their own control was, in 1879, one in 7,503,000 killed and one 934,700 inured; but if the Tay Bridge disaster is excluded from the computation, the proportion killed would only be one in 281,366,500, or less than in any year on record. In 1878 the proportion was one in 23,540,000 killed and one in 481,600 injured. Excluding ten injuries under the head of miscellaneous, 101 train accidents have been inquired into and reported on by officers of the Board of Trade in 1879, as against 108 for 1878. The report considers the year satisfactory on the whole, but concludes with a hope that a complete adoption of the block and interlocking systems, of continuous footboards with proper platforms, and especially of improved brake-power will no longer be delayed.

ORDNANCE AND NAVAL.

The New Breech-Loading Field Guns. The first battery of breech-loading guns, designed for the use of the Royal Horse Artillery and Field Brigades, was issued for service from the Royal Gun Factories, Woolwich, last week, having first been inspected and passed. They will in the first place be sent to Exeter and placed in charge of F Battery, B Brigade, Royal Horse Artillery, for the purpose of testing their efficiency by a series of rough work at Oakhampton, in competition with muzze-loaders, the test being irrespective of power and accuracy which have been already established at Shoeburyness, but designed to ascertain the suitability of the new weapons for the knocking about amidst dust and mud and bad weather which they must expect on active service. Should they pass through the trial with satisfaction, they will probably be transferred for more extended duty and under other conditions to G Battery of the same brigade. The guns have been constructed as far as practicable, seeing that they are breech-loaders, on the model of the muzzle-loading 13-pounder, which is the most highly regarded specimen of British ordnance, but are somewhat longer by reason of the breech arrangement. Both are of 3-inch caliber in the bore, which is in each 34 inches long, and enlarged to 6½ inches in the powder chamber, but while the muzzle-loader was regarded as of an extreme length at 7 feet 4½ inches, the breech-loader measures over all no less than 7 feet 7¾ inches, and looks a very slender cannon indeed. The apparatus at the breech is extremely simple, and no less effective. A turn of a lever unlocks the breech-piece, which when withdrawn, is seen to be a solid drum of metal, about 10 lbs. in weight, which screws into the gun by a thread surrounding the whole cylinder except at intervals where horizontal ways are smoothly cut, so that the drum can be readily drawn out when in position to clear to retaining jambs. A half turn of the screw thus releases it in a second, and being received by a carrier, it swings round on a hinge to the right, leaving the open breech clear for loading. Before this takes place a tube is inserted to protect the screw and ease the way, and through this tube the elongated projectile and cartridge are passed, when the breech-block is swung back, run home, and screwed fast by the locking lever in less time than it takes to describe the operation. Much ingenuity has been expended in obviating the possible danger of firing the gun before the breech is properly closed, which was the great drawback of the old breech-loaders, and four separate devices will be tried with this object. Three of the guns are fitted with a slide which covers the vent and cannot be removed until the breech is locked, when it may be drawn back by the gunner, and the three others have different contrivances for doing the same thing automatically and placing the safety slide beyond the gunner's control. The fittings are of bronze, formerly called gun-metal, but the metal of the gun is chiefly steel. The whole of the chase or barrel is of steel, and it is only in rear, where the greatest strain of explosion takes effect, that wrought-iron coils are shrunk on to strengthen and support it. The lightness of the gun, which weighs only 8½ cwt., may be mainly ascribed to the employment of the material, and a concession is at once made to the advocates beth of steel and breech-loaders.

Range Finding.—Lieutenant Edwards, R. A., has recently called attention to the question of range finding by two papers which he has contributed to the Artillery Institution. The importance of this subject is such that a short notice of the present position of the question is desirable. The value of finding the range by instrument in preference to depending on trial shots was recognized by the committee at Oakhampton in 1875, who recommended that range finders should be issued to batteries, and that additional men and horses should be provided to enable the service to be effectually performed. Any one acquainted with the service would know that if this recommendation

was carried out it would prove that times were indeed changed. The great difficulty that has always beset and hampered the efficiency of artillery, especially in the field, is the difficulty in impressing the difference between hitting and missing. Few really recognize that the material effect of a magnificent troop of horse artillery depends on the actual number of hits they make in action ; that all the proficiency displayed in riding and drilling, all the smartness in turning out with well-fitted harness, all the science expended in the construction of guns and carriages, shells and fuses, are only valuable as tending directly or indirectly to one end, and that six well-intentioned but unskillful men may frustrate the object for which a battery has existed from its first formation in the course of a few hours, for many batteries have continued for many years and only been in action on a few occasions. In the Crimea a competition trial was instituted by General Codrington between our own field artillery and that of the French. Before coming into action the contrast in the appearance of the English and French batteries was very great In fact the latter appeared to be so sensible of it that they seemed to try to keep at a distance so as to avoid comparison. From the moment the firing began, however, the tables were turned, for the French scored exactly two shots on each target to each single English one. The French, it turned out, had a skilled marksman at each gun. On one occasion the English had a general, a colonel, and a lieutenant at one gun, who were all distinguished officers, but who had not the special skill of their French competitor. Unquestionably the inferiority made manifest in target practice would tell in action, though without its being possible to estimate it. What actually resulted after Okehampton was that batteries have been supplied with range finders, but no extra men have been allowed and instruction has been left very much to chance. Now the question needs to be grasped and carried out consistently with a distinct object to be effectually dealt with. If it is determined to have an accurate and high-classed instrument, then a supply of men specially skilled to its use must be secured. If this cannot be allowed there seems no intelligent alternative but to have a simple and comparatively inaccurate instrument, for any benefit due to the accuracy of the instrument is certainly dependent on that of the man using it. A beautifully correct instrument pointed incorrectly is obviously an anomaly ; for while it cannot benefit the user by its powers it troubles him by its complication. It should be decided by special experiments what can be achieved by each instrument, and at the cost of what application of time and men, and then suitable provision should be made for the full mastery of whatever one was adopted. Lieut. Edwards enumerates many, among them some which could not long be seriously contemplated, such as Elliott's telescope, the pocket sextant, and the prismatic compass. Some of his objections, however, are, we think, hardly reasonable. For example, he twice objects to instruments having a fixed base a yard long, as liable to be bent. The same objection might be urged against the rifle barrel of every infantryman. The principal instruments to be noticed are Nolan's, Watkins', Berdon's, and certain instruments of Edwards' and Weldon's. Of these Weldon's and one or two of Edwards' are the simplest. As to accuracy, there is little difficulty with the best instruments if the men are trained. Watkins' has the advantage of requiring only two men to use it, which can be done before the battery comes into action. Nolan uses the gun as a stand, which gives great steadiness, but slightly delays the first rounds. On the other hand, it might happen that men sent on in advance of the battery might mistake the point on which the commanding officer might decide to open fire in actual service, though in target practice no such doubt might arise. Lieut. Edwards, after discussing the present very imperfect system of instruction, suggests that an instruction center is needed, and an officer and staff of non-commissioned officers appointed, indicating that Aldershot is the best station for the purpose. We do not think that such a branch of instruction, however, ought to be separated from the school of gunnery. Perhaps the work might have to be chiefly carried out at Aldershot, both because practice over broken ground is necessary, and because a considerable force of field artillery is always there ; but we think that any instructing officers ought to report to the School of Gunnery, and be available to work there at times—for instance, when the Artillery auxiliary forces are there assembled. A small independent department such as Lieut. Edwards contemplates provokes continual jealousy and opposition.

BOOK NOTICES.

Publications Received.

Bulletin of the Philosophical Society of Washington, Vols. 1, 2 and 3.

Monthly Report of the Meteorological Bureau for September.

Manufacture of Charcoal in Kilns. By T. Eggleston, Ph. D.

Parting Gold and Silver in California. By T. Eggleston, Ph. D.

By courtesy of Mr. James Forrest we have received late paper of The Institution of Civil Engineers.

Small Motive Power. By Henry Selby Hele Shaw.

Researches on Explosives. No. 2—Fired Gunpowder. By Captain Noble, F.R. A.S.; F.C.S., and F. A. Abel, C. B.; F.R. S. London : Trübner & Co.

This quarto pamphlet is reprinted from the Philosophical Transactions of the Royal Society. It deals with one line of researches only, viz.: fired gunpowder. But this is by no means so simple a subject as might at first be inferred.

The chemical salts formed ; the heat generated ; volumes of permanent gases generated ; pressures ; actual temperatures of explosion ; position of the shot when combustion is com-

pleted ; total work performed in a gun tried, are a few of the leading topics discussed.

The results of trials and calculations are carefully tabulated.

Scientific Lectures. By Sir John Lubbock, Bart. London : Macmillan & Co.

A series of lectures by this eminent investigator is a welcome addition to literature of popular science. The writer's work is altogether a labor of love, but it is nevertheless assiduous and careful.

The topics of the present series are : 1st. On Flowers and Insects. 2d. On plants and Insects. 3d and 4th. On the Habits of Ants. 5th. Introduction to the study of Prehistoric Archæology.

The typography and illustrations of the book are exceedingly good.

Alphabetical Manual of Blowpipe Analysis. By Lieut.-Col. W. A. Ross. London : Trübner & Co.

The author of this work is known to blowpipe students by his larger work on "Pyrology."

In many respects the present manual is convenient. The reagents, reactions, implements used, and assays are arranged and fully treated in alphabetical order. It is therefore better adapted as a reference book to the needs of the practical worker than as an instruction book for the learner.

It is well printed, and illustrated with considerable fullness.

An Introduction to Pharmaceutical and Medical Chemistry. By Dr. John Muter, F.C.S. Second Edition. Philadelphia : Presley Blakiston.

This voluminous treatise is divided into two distinct parts, the first being theoretical and descriptive, and the second practical and analytical.

The first part treats with much fullness of elements and their compounds, with reference to their uses in medicine. The second part is quite a complete treatise on wet analysis, both qualitative and quantitative.

A limited space is devoted to the examination of medicinal preparations.

The work is large, and although without illustrations, seems to be a good compendium for the medical student.

MISCELLANEOUS

A Diffusive Lantern.—The globes of opal and ground glass used in connection with the Jablochkoff candle and other electric lights have considerable diffusive power ; but it is a drawback to their employment that they absorb from 30 to 50 per cent. of the total light produced in the arc. M. Clemandot appears to have found a better mode of spreading the illumination in forming the lantern of a double glass envelope stuffed with glass wool, spun by a peculiar process, so as to yield fibres 175 times finer than a human hair, and 45 times finer than the finest cocoon silk. The first public trial of M. Clemandot's lantern was recently made at the Magazins du Louvre, Paris. A globular form of lamp was originally tried ; but it was found that dust got into the wool and soiled it, so that a new shape had to be devised. This proved highly successful. The transparent part of the lantern is conical in shape and tapers downwards. The walls are made of united glass tubes, like Pandean pipes, each filled with glass wool, and closed at top and bottom to exclude dust. Not more than 15 per cent. of the total light is absorbed by this process ; the opacity can be varied at will by introducing less or more wool into the tubes ; and the light can be tinted any desired color, either by the stain given to the spun glass, or the tubes which build up the wall of the lantern.

Conventional Signs for Weights and Measures.—The International Committee of Weights, sitting at Paris, has decided upon a system of conventional signs for expressing decimal weights and measures, as initiated by the Swiss Government, and more recently approved by the Government of Italy, which has expressed its intention of using all its efforts to obtain the universal adoption of these signs.

The *Bulletin du Ministere des Travaux Publics* has notified its intention, in common with some other French publications, of using the same symbols, which are as follows :

Measures of Length.

Kilometer	km.
Meter	m.
Decimeter	dm.
Centimeter	cm.
Millimeter	mm.
Mikron (0.001 mm.)	μ

Superficial Measure.

Square kilometer	km².
Hectare	ha.
Are	a.
Square meter	m².
Square decimeter	dm².
Square centimeter	cm².
Square millimeter	mm².

Cubic Measure.

Cubic meter	m³.
Stère	s.
Cube decimeter	dm³.
Cube centimeter	cm³.
Cube millimeter	mm³.

Liquid Measure.

Hectoliter	hl.
Décoliter	dal.
Liter	l.
Déciliter	dl.
Centiliter	cl.

Weight.

Ton	t.
Metric quintal	q.
Kilogramme	kg.
Gramme	g.
Decigramme	dg.
Centigramme	cg.
Milligramme	mg.

The adoption of a common system of abbreviations wherever metric measures and weights are employed possesses many obvious advant-

ages, but it requires to be known in order to prevent confusion.

Mr. J. Ireland, well known in connection with improvements in iron foundry, cupolas, furnaces, and other plant, has, we are informed, established a small experimental works at Edward street, Broughton lane, Manchester, in which trial samples of cast iron, wrought-iron, steel, spiegeleisen, or ferro-manganese, can be made direct from the ore in any quantity from one pound to one ton. Even after the discovery of what may be valuable material, great difficulty has often been found in getting iron-makers to smelt a small quantity for trial, and development of mineral fields has been thus postponed, and it will no doubt be of service to many to be able to obtain a sample product, on a large scale, of any mineral; and should there be fuel, limestone, and fire-clay found along with or in proximity to the ore, the samples of metal can be made with those materials if they are found suitable for the purpose.

Silvering by Cold Rubbing.—Make paste by thoroughly grinding in a porcelain mortar, out of the light,

Water	3 to 5 oz.
Chloride of silver	7 oz.
Potassium oxalate	10½ oz.
Salt (common table)	15 oz.
Sal ammoniac	3¾ oz.
Or,	
Chloride of silver	3½ oz.
Cream of tartar	7 oz.
Salt (common)	10½ oz.
Water, to form a paste.	

Keep in a covered vessel away from the light. Apply with a cork or brush to the clean metallic (copper) surface, and allow the paste to dry. When rinsed in cold water the silver presents a fine frosted appearance, the brightness of which may be increased by a few seconds' immersion in dilute sulphuric acid or solution of potassium cyanide. The silvering bears the action of the wire brush and of the burnishing tool very well, and may also be "oxidized." Should a first silvering not be found sufficiently durable after scratch-brushing, a second or third coat may be applied. This silvering is not so adhering or white on pure copper as upon a gilt surface.

For the reflector of lanterns the paste is rubbed upon the reflector with a fine linen pad; then, with another rag, a thin paste of Spanish white or similar substance is spread over the reflector and left to dry. Rubbing with a fine clean linen rag restores the luster and whiteness of the silvered surface.

The paste is sometimes mixed directly with the whiting and left to dry, or until nearly dry, then rubbed down as described.

Relative Cost of Motive Power.—Herr Bissinger, of Carlsrube, Germany, gives the following results as obtained in his examinations of the several motors in regard to the relative per horse power for each hour. It will be observed that the examination pertained principally to small motors. The relative cost per effective horse-power per hour is as follows:

100	horse-power	steam engine	7.6
2	"	"	44.3
2	"	Lehmann's caloric engine.	26.5
2	"	Hock's motor	40 0
2	"	Otto gas engine.	26.4
2	"	Otto Lang gas engine	26.4
2	"	Schmidt's hydraulic motor supplied with water from the city water works	95.00
2	"	obtained by horses and a gin	45.00
2	"	obtained by manual labor	200.00

Otto's gas motor and Lehmann's caloric engine are the cheapest of the small motors, but they are, nevertheless, four times as expensive as the 100 horse-power steam-engine.

The following is a carefully prepared table showing the population of ten Western States for the years 1860, 1870, and 1880 :

	1860.	1870.	1880.
Ohio	2,339,511	2,665,260	3,100,000
Indiana	1,350,428	1,680,637	2,056,500
Illinois	1,711,951	2,539,891	3,125,000
Missouri	1,182,012	1,721,295	2,200,000
Michigan	749,113	1,184,059	1,600,000
Wisconsin	775,881	1,054,670	1,305,000
Iowa	674,913	1,194,020	1,745,000
Minnesota	172,023	439,706	776,714
Kansas	107,206	364,399	900,000
Nebraska	28,841	122,993	452,000
Total	9,091,879	12,966,930	17,260,214

—*Bulletin.*

Some years ago a great deal of anxiety was expressed by the most sagacious railroad managers about the probable entire loss of worn-out steel rails. They knew that iron rails when worn out could be rerolled, but it was said that Bessemer steel rails could not be rerolled in the same way, and that therefore when unfit for further use in the track they would be cast aside as valueless. Gradually however, as steel rails have been taken up they have been used by steel-manipulating works, which have themselves expanded with the steadily increasing supply of old steel rails, and now the St. Louis *Age of Steel* says: "There is considerable demand for old steel rails at $40 per ton, while the supply is not at all commensurate therewith. Old steel rails are now being used for so many purposes that the supply is not at all equal to the wants of business." —*Bulletin.*

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The last number of the transactions is at hand, containing the following papers :

No. 203. Tensible tests of cement, and an appliance for more accurate determinations. By D. J. Whittemore.

" 204. Waterproof Coverings. By F. Collingwood.

Discussions on the above and upon papers 181 and 191 conclude the number.

// VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXLIV.—DECEMBER, 1880.—VOL. XXIII.

THE RELATION BETWEEN THE TENSILE STRENGTHS OF LONG AND SHORT BARS.

By W. S. CHAPLIN, Professor of Civil Engineering University of Tokio, Japan

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

To find the tensile strength of any material, it is customary to break a number of specimens, and take the average of the breaking weights as the ultimate tensile strength of the material. The strength of the individual specimens varies from the average, and of these variations it may be said that—

1°. Positive and negative variations are equally probable;

2°. Small variations are much more probable than large ones; and

3°. If the material be good, extremely great variations seldom or never happen.

Three similar propositions form the basis of the law of probability of accidental errors; namely,

1°. Positive and negative errors are equally probable;

2°. Small errors are much more probable than large ones; and

3°. Very large errors do not occur.

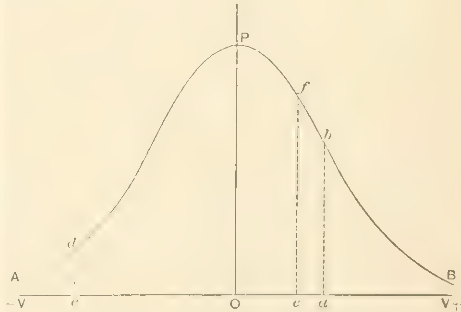
From this it seems reasonable to expect the variations in the strength of a material to follow the same law as accidental errors; or, what amounts to the same thing, it appears that we may consider the variations as accidental.

As an experimental proof that the laws in the two cases are the same, we may compare the number of times in which the variation in the strength of copper wire fell between certain limits, with the number of times it *should* by the law of error fall there.

Variation.	By experiment.	By theory.
Between 0 and .5P	46	46
" .5P " .P	51	43
" P " 1.5P	31	32
" 1.5P " 2P	28	25
Above 2P	24	34
	180	180

Considering that the breaking weights were taken in twentieths of a pound, and the averages calculated to hundredths, the agreement between the two sets of numbers is as great as could be expected.

Fig. 1.



It may be useful to explain to some extent the law of errors. It is represented by a curve which has a shape similar to AB (Fig. 1). The ordinates of

this curve represent probabilities; the abscissae errors. The probability of a positive error Oa is ab; of a negative error Oc, is cd. The whole area included between the curve and the axis of errors is equal to unity. The probability that an error will fall between $+Oa$ and $-Oc$ is given by the area $dcabPd$. The curve is symmetrical with regard to the line PO, as it should be from the first proposition on errors; hence, the area $APO = BPO = \frac{1}{2}$. If an ordinate be drawn dividing the surface BPO, or APO, into two equal parts, the error which corresponds to this ordinate is called the *probable error*, and it is defined by the fact that errors numerically greater than the probable error are equally probable with errors numerically less than the probable error. If Oe is the probable error, $POef = \frac{1}{4}$. The probability that an error will be either negative or less than the probable error is $\frac{3}{4}$. The probability that an error will be either positive or less than Oc is equal to the area $dcBPd = .5 + dcOPd = .5 + A_c$.

Substituting "variation" and "probable variation" for "error" and "probable error," we may apply the law and the curve to the variation in the strength of a material.

The doctrine of probabilities teaches that, if the probability of an event be p, the probability that it will happen n times in succession will be p^n; for example, if a coin be tossed up, the probability that it will fall with the head up is $\frac{1}{2}$; that it will fall n times in succession with the head up is $(\frac{1}{2})^n$. In like manner if a number of pieces of iron one inch long give an average ultimate tensile strength of 60,000 lbs. per square inch; the probability that any other similar piece will have a strength greater than this is $\frac{1}{2}$; that two pieces in succession will have a greater strength, $\frac{1}{4}$; that n pieces in succession will be stronger than the average, is $(\frac{1}{2})^n$.

Suppose that many pieces of cross section c, and length one inch have been tested for tensile strength with an average result S_0, and a probable variation in one piece of P_0; what will be the probable average strength, S_n, of pieces of the same cross section and a length n inches?

Knowing the probable variation in a piece one inch long, we are able to construct the curve showing the probability of any and all variations in a piece of this length. From this curve we can obtain the probability that the piece one inch long will break between any limits of variation. The probability that an inch-piece will break above a negative variation $-x$ is $.5 + A_x$, in which A_x represents the probability that the piece will break between o and $-x$. In a piece n inches long there are n pieces one inch long; the probability that any one of these will break above $-x$ being $.5 + A_x$, the probability that all of them will break above this limit, or that the strength of the whole piece will be at least $S_0 - x$, will be

$$(.5 + A_x)^n.$$

As S_x is an average, it is as probable that a piece n inches long will break above it as below it; hence the probability that a piece n inches long will break above it is .5. We have then

$$(.5 + A_x)^n = .5,$$

in which A_x is the unknown quantity. We easily obtain

$$A_x = \sqrt[n]{.5} - .5; \text{ or } 2A_x = 2(\sqrt[n]{.5} - .5).$$

The question is put in the last form to enable us to use tables, which are already prepared, showing the probability that an error, or in our case a variation, will be numerically less than a certain multiple of the probable variation. Such tables may be found in Merriman's Method of Least Squares, page 112; or in Chauvenet's Astronomy, vol. II., table IX A. Entering these tables with the argument $2A_x$ we find x; and as $x = \dfrac{\text{Variation}}{\text{Probable Variation}}$ we get

Variation $= x \times$ Probable Variation.

It will be seen that if n is greater than one, x must necessarily be negative; hence we conclude that as the length of pieces is increased, the probable average strength is diminished. This has been shown experimentally many times; for example, Trautwine (Engineer's Pocket-book, page 179) mentions an experiment made by Lieut. Shock, in which a specimen of steel whose length was small (turned down at one point) gave a strength of 79½ tons; when turned down for a length of 14 inches, it bore only 60 tons. Kirkaldy (experiments on wrought

iron and steel) gives experiments on specimens of three kinds of iron, which were turned down at a point, and for over three inches, and in no case did the long specimens have as great tensile strength as the short ones.

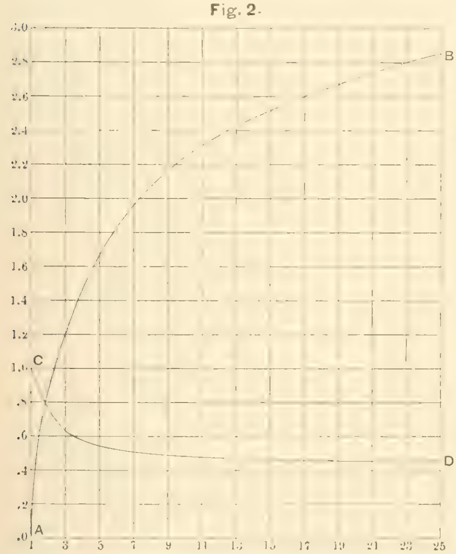
If now we place $n=1, 2, 3$, &c., and find the corresponding values of x, we shall have the diminution of strength for these lengths in terms of the probable variation of one specimen one unit long. The following table gives the values of x for values of n from 2 to 28:

Table Showing the Probable Loss of Tensile Strength from Increasing the Length of the Piece n Times, x Being in Units of the Probable Variation of a Specimen of a Length Unity.

n	x	n	x	n	x	n	x
1	0	8	2.05	15	2.51	22	2.78
2	.81	9	2.14	16	2.56	23	2.80
3	1.21	10	2.22	17	2.60	24	2.82
4	1.48	11	2.29	18	2.64	25	2.85
5	1.67	12	2.36	19	2.67	26	2.87
6	1.83	13	2.41	20	2.71	27	2.90
7	1.95	14	2.46	21	2.74	28	2.92

The curve AB in Fig. 2 shows the same thing, the multiples of n being measured horizontally, and the multiples of the probable variation of a single piece unity long being measured vertically.

Fig. 2.



As a proof of this theory, and as an example of the necessary calculations, I will give the following test made on annealed wire of Japanese copper: All the tests made in this set are given except two, in both of which the wire slipped in the clamps; one of these was a 1 inch piece, which when tried again broke at 26.25; the other, a 4 inch piece, broke afterwards at 27.15. As the ultimate strength of the wire is changed by straining it beyond its limit of elasticity, these two tests were discarded. The lengths were measured between the clamps of the testing machine; the specimens were cut off of the coil as they were tested, first a 1 inch specimen, then a 4 inch specimen, then 8 inch, 12 inch, 16 inch specimens and so on again through the series. When a wire slipped, another specimen of the same length was immediately cut off and tested.

Tensile Strength of Annealed Wire of Japanese Copper.

Length.	1 in.	4 in.	8 in.	12 in.	16 in.
Pounds.	27.35	27.00	27.00	27.00	26.90
	27.55	26.90	26.60	26.45	26.10
	26.30	26.20	26.25	26.10	25.90
	26 90	26.45	25.90	25.65	26.15
	26.80	26 40	26.40	26.20	26.20
	27.30	26.90	26.70	26.55	26.65
	27.35	26.90	26.60	26.45	—
Average	27.08	26.68	26.49	26.34	26 32
Prob. variation of one piece..	± .295	± .20	± .21	± .28	± .25
Prob. variation of average....	± .12	± .08	± .09	± .11	± .10
Loss of strength by exp't......		.40	.59	.74	.76
Loss of strength by $x\times 29.5$....		.436	.604	.70	.754

It will be seen that the loss of strength found by experiment agrees very closely with that found by the formula $x\times 29.5$.

If now we place

$$(.5+A_{x_1})^n=\tfrac{1}{4}$$

and find the value of x_1, this value of x_1 will be that multiple of the probable variation of one piece of length unity,

which corresponds to the probable variation for a piece of a length n.

Solving, we have

$$A_{x_1} = {}^{n}\sqrt{\tfrac{1}{4}} - .5 = {}^{2n}\sqrt{.5} - .5.$$

We can easily get the value of x_1 from our table by using the argument $2n$ instead of n. Then $(x_1 - x) \times$ probable variation of one test piece = probable variation of piece whose length is n. Thus we find for

4 in.	8 in.	12 in.	16. in
±.17	±.16	±.13	±.12

It could not be expected that the probable error found by so few experiments would agree with that given by the theory; yet for all the experiments on long pieces it is less than for the one inch pieces.

The curve CD Fig. 2 shows the probable variation of strength of a bar n units long, in terms of the probable variation of a bar a unit long.

In rolled bar irons, as the smaller sizes have been re-heated more times than the larger ones, and are more thoroughly rolled, it is probable that there is no law giving with any great accuracy their relative strengths. In forged bars, however, it is more probable that the material in bars of different sections is uniform, consequently their relative strengths can be calculated.

If a test-bar of one inch section has a strength of S_0, it is probable that a bar of the same length and of a section m times as great would have a strength mS_0. If the probable variation of the test-bar be P_0, that of the second bar will be $\sqrt{m}P_0$. The relative probable variation, or the probable variation divided by the probable strength, therefore, becomes smaller as the section of the bar is made larger.

Let us now apply these two laws to an example. Suppose a test of many pieces one foot long and one square inch in section, shows that the average tensile strength of such pieces is 60,000 lbs. with a probable variation of 10,000 lbs.; what are the probable strength and probable variation of a bar whose length is 20 ft., and whose section is 9 inches?

The probable strength of a piece one foot long and nine inches in section is 540,000 lbs.; and its probable variation $3 \times 10{,}000 = 30{,}000$. Increasing the length 20 times its probable strength is diminished $30{,}000 \times 271 = 81300$; hence its probable strength for a length of 20 ft. is $540{,}000 - 81300 = 458{,}700$. The probable variation from this is $(3.14-2.71)\ 30000 = 12900$ lbs.

It is to be hoped that those who have testing machines and occasion to make numerous tests will publish either all their individual results, or will give the probable variation as well as the average strength of the materials which they study. It really tells but little about a material to give only the average breaking weight; uniformity of strength, or a small probable variation, is a very valuable quality, and without knowing whether a material has a small probable variation or not, no engineer can properly decide what factor of safety shall be used in designing a structure.

THE PRACTICAL STRENGTH OF BEAMS.

By BENJAMIN BAKER, M. Inst, C. E.

From Selected Papers of the Institution of Civil Engineers.

The theory of transverse stress has engaged the attention of mathematicians for many years, and certain hypotheses have been, and still are, generally accepted, although every practical engineer knows that, in the majority of cases, the calculated results based upon these hypotheses are widely at variance with those obtained by experiment. Engineers, however, cannot afford to wait until a rational theory of transverse stress is agreed upon, and no doubt many engineers beside the author have framed certain rules for their own guidance, which have given results agreeing with experiment, and otherwise answered their purpose as well as if an unassailable theory had been arrived at.

A comparison of these practical rules can hardly fail to be useful, both to the scientific experimentalist who has leisure to make special tests to elucidate a theory, and to the engineer whose first object is to make sure that his structure possesses the required strength. The author, therefore, proposes to illustrate, as briefly as possible, the method of calculation which he has found, during the past fifteen years, to give satisfactory results in the instance of many thousands of tons of beams of every variety of cross section.

Of all classes of iron and steel beams, rails hold the most important position; for not only do they outnumber all other descriptions of beams by hundreds of millions, but at least a thousand pieces of rails are tested to destruction, purposely and in actual work, for every single specimen of rolled joist or riveted girder. Rails, therefore, and at the present time steel rails, are entitled to first consideration, and the general applicability of the methods of calculation set forth will be subsequently tested by a comparison of the calculated and experimental results in the instance of other forms of beams and girders.

The experience gained from the tests of upwards of a hundred thousand tons of steel rails, has satisfied the author that there could be no more fallacious way of comparing the merits of two sections of rail, as regards strength, than by taking a specimen of each at random and testing one against the other as a beam. As ordinarily manufactured the strength of steel varies so widely that by such a process it might be concluded that a 60-lbs. rail was as strong as an 84-lbs. rail, both being well designed sections and of a good quality of steel. A large number of specimens must be tested to obtain average results equally trustworthy with those which can be obtained by any unskilled person, in less than an hour, by the simple mechanical process of investigation set forth in this paper.

Although the stress occurring upon a rail in actual work is a matter outside the limits of theoretical investigation, it has been conclusively demonstrated in practice that a certain transverse strength is desirable; and it is expedient, therefore, for the engineer in all cases to ascertain whether a proposed rail possesses that desirable strength or not.

On paper, the problem presented by a cross-sleeper road appears to be identical with that of a continuous girder bridge of seven or eight spans, and the late Mr. Heppel and many others have so treated it. As a matter of fact this method is entirely wrong, both on theoretical and practical grounds. Theoretically so, because the rail rests upon elastic supports in the form of compressible wooden sleepers, and practically so, because of the uncertainty as regards packing of ballast and state of decay of the timber. The experiments of Baron von Weber, M. Inst. C.E., have shown that an average wooden sleeper compresses about one-fifth of an inch under a pressure equivalent to the weight on a heavy driving wheel; and as an ordinary rail would deflect only that amount if the sleeper were entirely removed, and the rail supported by the adjoining ones, it will be seen at once how utterly misleading must be any conclusions based upon the hypothesis of rigid supports.

Probably the most correct hypothesis will be to look upon a rail in the same light as the distributing girder of a suspension bridge, since, within certain limits, the required strength will not be affected by the distance apart of the points of support or suspension. Take for illustration the common case of a flange rail, laid direct on a bridge floor, formed simply of 8-inch planks spanning the 14 or 15 feet space between the main girders. Here the deflection of the rail between any pair of the most heavily loaded wheels will be small compared to the deflection of the planking, so the rail acts as a true distributing girder with calculable strains. To distribute the weight, say, of a 45-ton six-wheeled tank engine having a 15 feet wheel base, with approximate uniformity over the planking, the rail must obviously be strong enough, as an imperfectly continuous beam of 7 feet 6 inches span, to carry a distributed load of at least 1 ton per lineal foot. Allowing one-half of the maximum reduction obtainable by perfect continuity, the maximum bending moment on the rail will be $\frac{5\times7.5^2\times12''}{6\times8} = 70$ inch-tons—a stress

which an 80-lbs. iron rail could very well sustain, as it would be about one-fourth of the breaking stress.

Having reference to the elasticity of the sleepers, imperfections in packing, and other contingencies, it is probable that the above case not unfairly represents the condition of a rail in an ordinary piece of permanent way; and it follows that, however close the sleepers be spaced, even to touching, the rail must have the stated transverse strength, or it will not distribute the weight over the ballast without itself being strained beyond the limits found advisable in wrought-iron structures subject to repeated bendings.

Again, practical contingencies as regards decayed sleepers, and bad ballasting, clearly indicate that the strength of the rail in a cross-sleeper road should be sufficient to carry the load without exceeding the limit of elasticity, even if one intermediate sleeper were wholly removed from under the rail. Allowing as before for imperfect continuity, it will be obvious that the distance apart of the sleepers must be something less than one-fourth of the wheel base of the before-mentioned 45-ton tank engine, or 3 feet 9 inches, or the stress would be double that occurring on the planked floor, and consequently reach the limit of elasticity. With the sleepers 3 feet apart, the 80-lbs. iron rail would not be permanently bent by the heavy engine, even if an intermediate sleeper failed, as in practice is often the case, to yield any support to the rail.

On the Metropolitan railway the average breaking weight of the original rail, when partly worn, would not be more than 16 tons, if one of the intermediate sleepers failed to support the rail. As the weight on the driving wheel is 8 tons, plus the amount due to oscillations and other contingencies in working, it follows that, under the latter conditions, the strain would pass the limit of elasticity, and that after repeated bendings, the rail would break through the holes in the bottom flange. This was found to happen in so large a number of instances as to indisputably establish the fact that the limit of elasticity was frequently passed, and that the repeated bendings under the five-minute train service broke the rails by tension at a point where, if the supports were only approximately rigid, compressive strains alone would occur.

There are sound theoretical grounds, therefore, for the conclusion, long since arrived at in practice, that an 80-lbs. iron rail, with sleepers 3 feet apart, is the lightest permanent way which it is expedient to adopt for heavy traffic, if it is intended to avoid strains beyond the elastic limit, and the "bad top" so characteristic of not a few lightly railed but heavily-sleepered American lines.

A steel rail on the average may be considered as about 50 per cent. stronger than an iron rail of the same section, and it was not unreasonably assumed at first that the introduction of steel would lead to the use of correspondingly lighter rails; but this has not proved to be the case in practice, probably for the following reasons: The effective strength of a rail is not its strength when new, but when worn, and as a steel rail is expected to become disabled only by fair wearing away of the head for $\frac{3}{4}$ inch, or even more, and not by crushing or lamination, it is necessary to compare the strength of the steel rail so worn with that of the less worn iron rail; and if this be done it will be found that a considerable call is ultimately made upon the increased strength of steel, though the rails when new be of the same weight. The reintroduction of the "bull-headed" rail of 1835 is both scientifically and practically right, because it provides a large area for wear in the head, and recognizes the fact that the top and bottom tables of a rail are each subject to alternating tensile and compressive strains of equal intensity, and require therefore in the worn rail equal areas. A well-proportioned bull-headed steel rail will lose at least 25 per cent. of its weight, and 25 per cent. of its strength before the top table is unduly worn; so, having reference to this fact, and to the great variation in the strength of the steel in rails, it would be clearly inexpedient to make the large reduction in weight, which superficial investigation might at first indicate, as a consequence of the substitution of steel for iron.

A consideration of the probable strains occurring in a rail is of great interest, as affording, beyond all comparison, the most

important data for arriving at trustworthy conclusions in matters relating to the endurance of iron and steel under severe stresses. As already observed, no other class of beam includes a tithe of the number of examples, nor is any other description of beam subjected to the millions of repeated bendings, and instantaneous reversal of strains, that a rail undergoes in ordinary working.

One consequence of the substitution of steel for iron rails has been a greatly increased difference in the maximum and minimum strength of a given piece of permanent way. It is extremely difficult to ensure even a moderate degree of uniformity in the strength of the steel rails, manufactured from a given specification. In one lot of about 20,000 tons, rolled in three different works, the author found in each instance that the tensile strength of rejected rails ranged at times from about 32 to 54 tons per square inch, though the average of the whole, judging from the tests, must have been within 5 per cent. of that aimed at by him, namely, 40 tons. Here there occurs a range of nearly 70 per cent., which is far greater than anything the author has met with in the instance of iron rails. It is worthy of note that the recent exhaustive inquiry, of the Pennsylvanian Railroad Company, into the comparative endurance of rails of different degrees of hardness, has led to the specification of steel having as low a tensile strength as 29 tons per square inch. Steel rails of this description would be little more than 10 per cent. stronger than good iron rails of the same section, and considerable further experience is required before this great sacrifice of strength can be said to be justified. Where the pernicious plan of making holes in the flanges of rails is still in force, as it is on some Irish lines, the steel undoubtedly can hardly be too soft; and in such cases the author aims at a mean tensile stress not exceeding 35 tons per square inch, in lieu of the 40 tons which he otherwise adopts.

Although the tensile strength and ultimate extension afford perfectly satisfactory evidence of the quality of steel in the form of rails, the necessary tests are inconvenient and costly in application. The rough-and-ready falling weight test is simple and effective, but it is not possible to deduce directly therefrom the strength and ductility of the steel. The lever test is next in order of simplicity, and the results thus obtained, when properly interpreted, do disclose those elements, as completely as if the cost and labor had been incurred of planing out strips and testing them under direct tensile stress. Some simple and trustworthy plan, of converting results obtained under transverse stress into the equivalent results under direct tensile stress, is thus a desideratum of no little practical importance; and the author now submits the method which he has found satisfactory in the instance of many thousands of tons of rails of varied sections.

The average results of a very large number of experiments show that as regards deflection under transverse stress, a rail as a beam behaves exactly in accordance with the ordinarily accepted theory, with this important distinction, that the maximum deflection within the elastic limit is greater than theory would indicate, by an amount ranging from 5 to 50 per cent., according to the cross section of the rail. Experiments by Mr. W. H. Barlow, F.R.S., President Inst. C.E., on other descriptions of beams would have indicated such a conclusion, and that the increase in the elastic deflection, as in the elastic and ultimate strength, must necessarily be included within the limits of 0 and 70 per cent., because the increase is nil in the instance of a steel-plate girder with a thin web, and averages 70 per cent. in a solid bar of rectangular cross section. In estimating the probable increase in the case of a beam, such as a rail having a cross section between these two extremes of girder and bar, the first impulse naturally would be to assume that it would approach the limit of 70 per cent. in the same proportion as the section of the rail approached the solid rectangular bar, that is to say, that the increase would be 70 per cent., multiplied by the sectional area of the rail, and divided by the area of the enclosing rectangle. This simple assumption the author has found to be sufficiently near the truth for all practical purposes, as it leads to equally useful results when applied to a 5-inch flange rail—the widest now rolled—and to a bull-headed

rail with a 2-inch bottom flange. Any great refinement in calculations of this sort is wholly unnecessary, for there is good reason to suppose that every cubic inch of steel in a rail differs somewhat in tensile strength from its neighbor, whilst internal tension and other elements further complicate results. All that can be attained, and all that is practically necessary, is a knowledge of the relative strengths of different cross sections of rail, and of the absolute strength of a given rail made of steel of a stated tensile strength, within a sufficiently small percentage of the actual results obtained, not in a few, but in a fairly large number of direct experiments.

Accepting the above hypothesis as to increased strength under transverse stress, it is only necessary to know the moment of resistance of the cross section of the rail as a girder, or the effective depth in inches multiplied by the effective flange area in square inches, to be enabled to convert results obtained under transverse stress into their equivalents in direct stress.

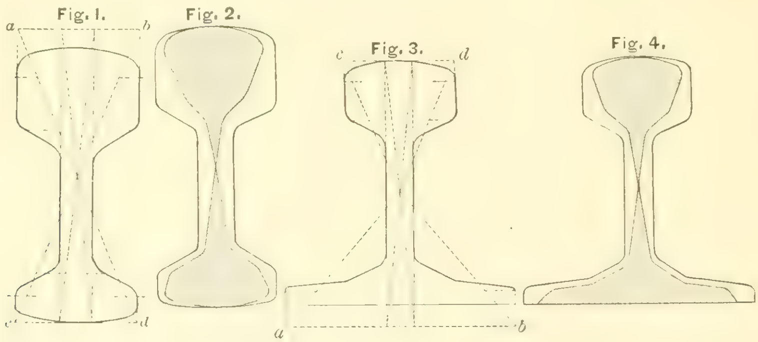
The required moment of resistance, and other information, are readily obtained mechanically as follows:

1st. Cut a template of the rail out of a sheet of tin-plate or thin zinc, and also a strip 1 inch wide, and about 10 inches long. Place the template in one of a pair of letter scales, or cheap laboratory scales, and balance it by cutting a portion off the 1-inch-wide strip. The length so cut off will obviously give the area of the rail in square inches, and this multiplied by ten will be the weight in pounds per yard if of iron; if of steel, add from 2 to 3 per cent.

2nd. Balance the template flatwise on the point of a needle to obtain the center of gravity and neutral axis of the given cross section.

3rd. Transfer the neutral axis so obtained to the drawing of the rail. In the bull-headed section this axis will of course be nearer the top than the bottom of the rail, in the flange section generally the reverse; in either instance set up, or set down, as the case may be, a horizontal line *a* to *b* at the same distance from the neutral axis as the part *c* to *d*. By a series of perpendicular lines, transfer the width of rail flange, thickness of web, &c., to the lines *a* to *b* and *c* to *d*, and draw lines radiating to the neutral axis, as shown on Figs. 1 and 3, the intersection of which, with the horizontal lines indicating the thickness of head and flange, &c., will at once give the boundaries of the areas of uniform stress, as shaded on Figs. 2 and 4.

4th. Cut templates of these figures



out of tin-plate or zinc as before, place one in each scale-pan of the balance, and if correctly executed, the weight of the portion above the neutral axis will exactly balance that below. Put both templates into one pan, and balance them by cutting a portion off the 1-inch-wide strip, when the length so cut off divided by 2 will of course give the area of each template, or as it may be termed the effective flange area of the rail.

5th. Balance each template on the point of a needle to obtain the center of gravity. Transfer these centers to the drawing, and the distance between them will give the effective depth of the rail, which multiplied by the area will give the required moment of resistance. The latter may also be quickly obtained with

a sufficient degree of accuracy by cutting the templates out of drawing-paper, and finding the centers of gravity as before by balancing, but calculating the areas instead of weighing the templates.

The moment of resistance so determined, will be the minimum moment applying to the lower portion of a bull-headed rail, and, generally, to the upper portion of a flange rail. The effective moment of resistance for the other half of the rail will obviously be greater, in the inverse ratio of the distances of the extreme fibers from the neutral axis, as exhibited in the application of the above method of calculation to the solution of the following problems respecting a bull-headed rail and a flange rail:

a. A bull-headed rail, 5.6 inches deep, by 2.5 inches wide, weighing $82\frac{1}{2}$ lbs. per yard, sustains an ultimate load of 35 tons applied at the center of 60-inches bearings; required the equivalent direct tensile strength of the steel.

b. A flanged rail, 4.75 inches deep, by 4.75 inches wide, weighing $72\frac{1}{2}$ lbs. per yard, is made of steel having a tensile resistance of 43 tons per square inch, and an elastic limit of 54 per cent; required the weight applied at the center of 60-inches bearings, which the rail will support without permanent set.

Dealing first with the bull-headed rail:

1. On weighing the zinc template of the rail the sectional area is found to be 8.05 square inches.

2. On balancing the template on the point of a needle, the center of gravity, or neutral axis, proves to be 2.57 inches from the head, and 3.03 inches from the bottom flange of the rail.

3. The distance 3.03 inches being set up above the neutral axis, the figures of uniform stress are drawn, and templates in zinc prepared as already described.

4. On weighing the two templates, their joint area is found to be 4.8 square inches, and the "effective flange area" therefore is 2.4 square inches.

5. Balancing the templates on the point of a needle, the center of gravity of the upper template proves to be 1.74 inch above the neutral axis, and of the lower template 2.31 inches below the same point. The "effective depth" consequently is 4.05 inches, and the moment of resistance M = 2.4 square inches × 4.05 inches = 9.7.

The "apparent" tensile strain f on the steel under the given load of 35 tons at the center of 60-inches bearings will therefore be:

$$f = \frac{35 \times 60''}{4 \times 9.7} = 54 \text{ tons per square inch.}$$

The ratio of the rail to the enclosing rectangle is $\frac{8.05 \text{ sq. in.}}{5.6'' \times 2.5''} = 0.57$, which, multiplied by 70 per cent., gives 40 per cent. as the probable difference between the "apparent" tensile strength developed under transverse stress, and the direct tensile strength of the steel of which the rail is made. Dividing the calculated 54 tons "apparent" strain by $1+40$ per cent., the equivalent direct tensile strength $= \frac{54}{1.4} = 38.6$ tons per square inch.

Referring to Mr. Price Williams' paper on the "Permanent Way of Railways," from which, for convenience of reference to the already published table of tests, the above example was taken, it will be found that in the four samples tested, the mean ultimate load at 60-inches bearings was 35 tons, and the mean direct tensile strength of the steel strips, cut out of the bottom flange, 39 tons per square inch.

The method advanced gives, therefore, satisfactory results as regards the bull-headed rail, and its applicability to the flange rail section will now be tested.

Proceeding with the $72\frac{1}{2}$-lbs. flange rail in the same manner as with the $82\frac{1}{2}$-lbs. bull-headed rail, the following data are as readily obtained:

1. Sectional area of rail = 7.1 square inches base.

2. Center of gravity = 2.5 inches from head, and 2.25 inches from flange.

3. Effective flange area = 2.25 square inches.

4. Center of gravity of upper and lower areas = 1.75 inch and 1.85 inch respectively, from neutral axis. The "effective depth" therefrom = 3.6 inches, and the moment of resistance M = 8.1 in compression, and $8.1 \times \frac{2.5''}{2.25} = 9$ in tension.

5. Ratio of rail to enclosing rectangle $= \frac{7.1 \text{ sq. in.}}{4.75 \times 4.75} = .31$; which multiplied by 70 per cent., gives 22 per cent. as the

probable increased strength in this instance, instead of 40 per cent. as in the bull-headed section.

The "apparent" tensile strength at the elastic limit, under transverse stress, with the given conditions of 43 tons ultimate direct tensile strength, and an elastic range of 54 per cent. will be 43 tons $\times$ 54 per cent. $\times$ (1+22 per cent.) = 28.4 tons per square inch; and the corresponding weight applied at the center of 60-inches bearings required to produce an appreciable "set" will be:

$$W=\frac{4\times 28.4 \text{ tons } \times 9}{60 \text{ inches}}=17.04 \text{ tons.}$$

The mean result obtained by the author in six experiments, on rails having the direct tensile strength of 43 tons per square inch, was 17.2 tons; and equivalent results were obtained with numerous other specimens having higher and lower tensile strengths.

The simple hypothesis, that the increase in the transverse strength of a flanged or double-headed steel rail, beyond what the ordinary theory would indicate, is equal to 70 per cent. multiplied by the ratio of the sectional area of the rail to the enclosing rectangle, thus proves true in the two preceding, as it has in hundreds of other, instances tested by the author. In some recent examples, the bottom table of the rail is narrower than the top, the form of cross section approaching in fact to that of a ⊤ iron; and it is necessary to remark that the increase in such instances will be found equal to 70 per cent. multiplied by the ratio of the rectangle, formed by the width of the bottom table and the height of the rail, to the sectional area of the portion of rail enclosed in this rectangle. For a pure ⊤ section this of course would be equal to 70 per cent. multiplied by one, or, in other words, the increase would be the same as in a rectangular bar.

The following extreme case is selected for illustration of the practical sufficiency of the above empirical rule:

c. A built "channel" beam having $6\frac{1}{4}$ inches $\times$ $\frac{3}{8}$ inch web plate, and two angles $2\frac{3}{4}$ inches $\times$ $2\frac{3}{4}$ inches $\times$ $\frac{5}{16}$, made of steel having a specified tensile strength of from 27 tons to 31 tons per square inch, is tested, web plate uppermost, at 3-feet bearings; required the weight applied at the center which this beam would support without permanent set.

The elastic strength of the steel would probably range from about 15 tons per square inch to 10 per cent. above that amount. Cutting out a template of the beam in drawing paper, and suspending it, to find the center of gravity, and otherwise proceeding as in the instance of the rails, the "effective depth" is found to be 2.1 inches, the "effective flange area" 0.76 inch, and the moment of resistance = 2.1 $\times$ 0.76 = 1.60.

A distinct permanent set in this instance, according to the theory advanced, would not be produced until the apparent tensile strain in the vertical webs of the angle-irons was equal to, from 15 tons $\times$ (1+70 per cent.) = 25.5 tons per square inch, to 10 per cent. above that, or 28 tons per square inch, which is not far from the ultimate direct tensile strength of the steel.

The equivalent load in cwts., (W) applied at the center of 36-inches bearings, will be:

$$W=\frac{25.5 \text{ tons } \times 20\times 1.6\times 4}{36''}=90.6 \text{ cwts.}$$

With an apparent strain of 28 tons per square inch the value of W would be 99.6 cwts.

The weight indicated by calculation as that which the described beam would support, without appreciable set, may thus fairly be stated as from 90 to 100 cwts.

Referring to the "rigidity tests" in Mr. Martell's paper on "Steel for Shipbuilding,"* from which the above example was taken, the following will be found to be the results of direct experiment:

Between 0 and 90 cwts.
permanent set = 00009 inch per cwt.
Between 90 and 100 cwts.
permanent set = .00500 inch per cwt.

In this extreme case, therefore, calculation and experiment are in accord, as in both instances the required weight is found to be from 90 to 100 cwts.

In another experiment the angles were brought together back to back and riveted to the plate, thus making a built-up ⊤ beam, which was tested table

* Trans. Inst. Naval Architects, vol. xix., p. 20.

downwards at 36-inches bearings, with the result as before of showing a practical accordance between the theoretical and actual elastic strength.

The former beam may be looked upon as an exaggerated example of a rail with no bottom flange, and the latter, as that of a rail with wide bottom flange and no head; hence it is no matter for surprise that the method of calculation advanced gives satisfactory results in the instance of rails of every variety of cross section met with in practice. An extension of the method to rolled joists, deck beams and built girders of every description is equally admissible, if it be clearly borne in mind that at stresses above the elastic limit a beam may, and often does, fail from local weakness before the resistance of the metal has been fairly developed.

From many hundreds of experiments on beams of every variety of cross section, the author has been led to the conclusion that the elastic strength of a beam represents some 50 to 55 per cent. of the ultimate strength which will be developed, if the beam is free from local weakness. In the instance of rolled joists and built girders, the local weaknesses determining failure are generally narrowness of flange and thinness of web. A top flange may be made very narrow, if the bottom flange is wide and the web thick, as already instanced in the case of the inverted T-beam, and as will be further illustrated by the following example of an iron-flanged rail:

d. A flanged rail 4.56 inches deep by 5 inches wide at the foot, and $2\frac{1}{2}$ inches wide at the head, weighing 73 lbs. per yard, is made of iron having an ultimate tensile strength of 25 tons per square inch; required the ultimate strength at 48-inches bearings, assuming that the failure does not occur by the apparent local weakness of the relatively narrow top flange in compression.

Here the area of the rail = 7.3 square inches; the center of gravity = 2.14 inches from the bottom, and 2.42 inches from the top; the "effective depth" = 3.61 inches; the "effective area" = 2.28 square inches; the moment of resistance in compression = 8.23, and in tension = 9.3; and the ratio of the area of the rail to the enclosing rectangle = 0.32. The ultimate direct tensile strength of 25 tons per square inch, would be increased to 25 tons $\times$ $(1+0.32\times70$ per cent.$)=$ 30.5 tons per square inch, under transverse stress; and the ultimate load (W) would thus be:

$$W=\frac{9.3\times30.5\times4}{48}=23.6 \text{ tons.}$$

The preceding rail was one of a series tested for the author, and was returned as having an elastic strength of 11.6 tons, and an ultimate strength, under a deflection of 3.38 inches in the 4-feet span, of 23.7 tons.

The "apparent" compressive strain upon the head of the rail under this load would be 34.5 tons per square inch, hence the fair ultimate strength of about double the elastic strength was fully developed, notwithstanding the narrowness of the top flange of this beam.

In the above case, the relatively great width of the bottom flange, and the thickness of the web, compensated for the narrowness of the top flange, or the result would have been very different, as will be seen from the following typical example of the behavior of a rolled joist under transverse stress:

e. A rolled joist 12 inches $\times$ $\frac{5}{8}$ inch $\times$ 6 inches $\times$ $\frac{7}{8}$ inch, weighing 56 lbs. per foot, is made of iron, having an ultimate tensile strength of 24 tons per square inch; required the elastic transverse strength at a span of 20 feet.

Here the area of joist = 16.8 square inches, the moment of resistance = 63.6, and the ratio of the area of the joist to the enclosing rectangle = 0.23. In the fibrous iron of which joists are made, the maximum increase is generally 60 instead of 70 per cent.; hence, taking the elastic tensile strength at 50 per cent. of the ultimate, or 12 tons per square inch, the "apparent" elastic tensile strength under transverse stress will be, 12 tons $\times$ $(1+0.23\times60$ per cent.$)=$ 13.7 tons per square inch, and the required load at the center of 20-feet span will be:

$$W=\frac{63.6\times13.7\times4}{20\times12}=14.5 \text{ tons.}$$

By direct experiment the load proved to be 14.7 tons at the elastic limit; but in this instance, owing to the narrowness of flange, the full resisting power of the metal was never even approached, or the ultimate load supported would

have been about double the above, or 29 tons, instead of the 19.2 tons actually obtained. In fact, owing to lateral weakness, the joint behaved as joists usually do, and failed by lateral flexure under a calculated unit strain only one-third greater than the strain at the elastic limit, instead of at, or about, double the latter, as in the instance of the iron rail, and other examples, where the full power of the metal w s developed.

A beam may also fail through lateral flexure of the web, as instanced in the following examples of some riveted girders of the same span as the above, which the author had manufactured to elucidate this and other disputed points:

f. A riveted girder with a 24 inches × ½ inch web, and with five 8 inches × ½ inch plates, and two 3 inches × 3 inches × ½ inch angle-irons in each flange, is made of iron having an ultimate tensile strength of 21 tons per square inch, and an elastic strength of 50 per cent.; required the weight which would be supported at the center of 20-feet bearings without appreciable permanent set.

Here the moment of resistance in compression = 610, and in tension through the rivet holes = 432. Taking the mean of these = 521 as the effective moment in determining the point at which an appreciable set would occur—having reference to the fact of the plates being riveted, and not welded together, and for the latter reason also taking the increased strength under transverse stress as proportional to the minimum cross section of the girder (where there is only one 8 inches × ½ inch plate in the flange) and the enclosing rectangle; then the 10.5 tons per square inch elastic strength will become

$$10.5 \text{ tons} \times \left(1 + \frac{25.5 \text{ sq. in.} \times 60 \text{ per cent.}}{25'' \times 8''}\right)$$

$=11.3$ tons, and the required load will be

$$W = \frac{521 \times 11.3 \times 4}{20 \times 12} = 98 \text{ tons:}$$

which was the result obtained by the author by direct experiment.

It is not contended, of course, that the correction for the increased strength under transverse stress is of any practical moment in the instance of ordinary riveted girders; but it is introduced here rather with a view of showing that the correction does not conflict with experimental results even in the extreme case cited.

g. A riveted girder identical with the preceding, with the exception that the bottom flange was made of eight 5½ inches × ½ inch plates, and two 2½ inches × 2½ inches × ½ inch angle-irons, was similarly tested at 20-feet bearings, and failed by distortion under a load of 102 tons; required the tensile and compressive strains under that load.

Here the moment of resistance in compression was 630, and in tension 450; hence the required unit strains will be:

$$\frac{102 \text{ tons} \times 20 \times 12}{630 \times 4} = 9.7 \text{ tons}$$

per square inch compression;

$$\frac{102 \text{ tons} \times 20 \times 12}{450 \times 4} = 13.6 \text{ tons}$$

per square inch tension.

The previous experiment *f*, proved that the effective elastic strength of the flange in compression was at least as much as 9.7 tons per square inch, so this is a case in which failure occurred at, or below, the elastic limit, as far as the top flange was concerned. That the failure was not due primarily to the narrowness of the top flange is apparent at once, from the relatively high resistance of the joist at the same span, though the flange was narrower in the ratio of 6 inches to 8 inches.

A tabulation of the results obtained in experiments *d*, *e*, *g*, with some others, will render this still more apparent.

	Ratio of Span to Width.	Ultimate "Apparent" Compressive Strain.
d (iron rail)	20	34.5 tons per sq. in
e (" joist)	40	18.2 " " "
g (" girder)	30	9.7 " " "
h (" joist)	48	17 9 " " "
i (" ")	30	18.8 " " "

Experiment *h* refers to some joists 10 inches × 5 inches tested by the author at 20-feet spans, and *i*, to some joists 12 inches × 6 inches tested at 15-feet spans.

It is clear, therefore, that the failure of girder *g* was not due to narrowness of flange, but to the relative lightness of the web. The latter was much stiffer

than usual, as it was $\frac{1}{2}$ inch thick, in one length without joint, and stiffened every 5 feet with two 3 inches $\times$ 3 inches $\times$ $\frac{1}{2}$ inch angle-irons and two 5 inches $\times$ $\frac{1}{2}$ inch packing-strips under the same. Nevertheless, it did not suffice to maintain the rectangular connection of the several parts of the girder, and failure occurred by lateral flexure of the web at one end of the girder under a "shearing strain" of but $42\frac{1}{2}$ tons per square inch.

This experiment is sufficient to enforce upon the attention of engineers the fact that width of flange is not necessarily an efficient substitute for rigidity in the connections of the main girders of a bridge. The author in continental bridges has frequently employed flange-bars only 10 inches wide for lattice-girders of 66-feet span—a ratio of about 80 to 1; and in girders over 200-feet span he has been satisfied with a ratio of less than 110 to 1; but then the whole structure has been so rigidly connected together by gussets and bracing, that the top flange has had no more chance of evading its work than the head of the rail had in experiment *d*.

Two sources of local weakness, namely, deficient lateral stiffness of flange, and want of rigidity in the web and its connections, have now been illustrated; but there are others existent which would no less vitiate the results deduced from any general theory of transverse stress, and of these the most important is the following:

The strength of a plate web, according to Professor Airy, M. Bresse, and nearly every other mathematician, is governed by the resistance of the web to the diagonal compression due to the shearing stress. This may be practically true in some few instances, but it was not so in that of the 24 inches $\times$ $\frac{1}{2}$ inch web of girder *g*, or the shearing strain sustained would have been double the $4\frac{1}{4}$ tons per square inch, which crippled the web; neither was it even approximately true in the instance of some girders with 3 feet 6 inches $\times$ $\frac{1}{4}$ inch webs, which the author tested with the view of determining the real nature of the stresses in a plate girder as ordinarily constructed. These girders *k* were 31 feet 8 inches effective span, and the $\frac{1}{4}$ inch web was in five lengths of 6 feet 4 inches $\times$ 3 feet 6 inches plate, riveted together by T-iron stiffners 5 inches $\times$ 4 inches $\times$ $\frac{3}{8}$ inch, having stiffner-plates $\frac{1}{4}$ inch thick, and edge L-irons $2\frac{1}{2}$ inches $\times$ $2\frac{1}{2}$ inches $\times$ $\frac{5}{16}$ inch. The top flange was 20 inches wide by $\frac{1}{2}$ inch, with edge L-irons 4 inches $\times$ 4 inches $\times$ $\frac{1}{2}$ inch. The bottom flange was 20 inches $\times$ $\frac{3}{4}$ inch; and both top and bottom flanges were secured to the web by $4\frac{1}{2}$ inches $\times$ $4\frac{1}{2}$ $\times$ $\frac{1}{2}$ inch L-irons. The effective area of the flange in tension was 19 square inches, and in compression 26 square inches; so that, having reference to the width of flange, in all probability, the girder tested to destruction would have failed by tension, unless the web first failed. The author determined to test the elastic strength of the web of these girders. From previous experiments on similar girders with webs of double the thickness, he knew that, so far as the flanges were concerned, appreciable permanent set would not be exhibited until the tensile strain on the bottom flange exceeded 10 tons per square inch; and when, therefore, under a load of 70 tons, a slight set appeared, which at 75 tons had increased to more than $\frac{1}{16}$ inch, he knew that the set was wholly due to the web, because the unit strain on the flanges corresponding to the load of 75 tons was but 8.6 tons per square inch in tension and 6.25 tons in compression.

This load was applied opposite a stiffner, at a point distant 12 feet 8 inches and 19 feet from the respective abutments, and the maximum "shearing force,' therefore, would be 45 tons, or at the rate of 4.3 tons per square inch on the gross section of the web. The resistance of the thin web to diagonal compression would be less than a third of this, so the strength was obviously not governed by the conditions laid down in the ordinary theory. The permanent set of $\frac{1}{16}$ inch could not be due to excessive compressive strains on the web, because the total deflection of the girder was far too small to permanently bend such an elastic long column as that constituted by the $\frac{1}{4}$-inch web. It could only be due, therefore, to the stretching of the web under the diagonal tensile strains; and the lines of greatest severity of strain from the bottom of one vertical stiffener to the tops of the adjoining ones were plainly marked by an apparent buckling of the web along

those lines, when the girder was subjected to the stated load. From a careful consideration of the phenomena exhibited, the author was led to the conclusion that at a point in the center of the 6 feet 4 inches × 3 feet 6 inches web plate, where, by the ordinary theory, the diagonal strains would be about $4\frac{1}{2}$ tons per square inch both in tension and compression, the strains were as a matter of fact about 11 or 12 tons in tension, and half a ton, or a ton in compression. Rankine has shown how little the change of form in a plate web conduces to the total deflection of a girder; and, for similar reasons, a set of $\frac{1}{16}$ inch from web strains indicates very clearly the severity of the strains.

The author verified his experiments on the preceding girder by numerous others on five girders of equal size, but with varying proportions of flange and web, and obtained practically identical results. He also made models of the girders to scale, with wooden flanges and stiffeners, and paper webs. Testing these little girders to destruction, the lines of stress were indicated with conspicuous clearness; and the phenomena exhibited by the full-sized girders were exhibited also, in an exaggerated degree, by the models. Indeed, the latter experiments proved more suggestive than all the experiments on the iron girders, and all the mathematical investigations on the subject; and, after witnessing them, there was no difficulty in forming a clear idea of the nature and intensity of the strains occurring in a plate web as ordinarily constructed.

The local weakness in the preceding girders, which would have determined failure before the full strength of the flanges had been developed, was again thinness of web. In the three cases cited—the rolled joist, the 24 inches girder, and the 3 feet 6 inches girder—the strengthening of the locally weak portions would be a subject rather for practical experience than theoretical investigation. Many such cases are met with in practice, the minimum strength which must be provided in the bracing of the struts of lattice-girders being one such. So far as plate webs of medium size are concerned, the author is of opinion that the general conditions laid down by Mr. Chanute in his specifications for the Erie Railroad bridges, meet all the requirements indicated by experiment, and he cites these in preference to his own practice as being independently deduced. These are, that the "shearing strain" shall not exceed half that allowed in tension on the bottom flange of a riveted girder, and that when the least thickness of the web is less than $\frac{1}{80}$ of the depth of the girder, the web shall be stiffened at intervals not over twice the depth of the girder.

If judgment be exercised in the design of girders so as to avoid local weaknesses, then, according to the author's experience, the method of investigation which has been found to give trustworthy results in the instance of iron and steel rails will give equally trustworthy results in the instance of every other description of iron and steel beam.

The anomalies presented by beams of different cross sections, as regards strength, do not extend to their deflections except that, as already stated, the elastic range is increased.

The elastic deflection δ of a beam of any type, but of uniform cross section, of the depth d and span s, will for a central load be given by the following equation:

$$\delta=\frac{s^2 f E}{6d},$$

when f is the mean of the "apparent" maximum tensile and compressive strains upon the metal in tons per square inch, and E, the modulus of elasticity expressed by the extension or compression, in terms of the length, for each ton per square inch strain. For a uniform load, the divisor will become $\frac{24}{5}$, instead of 6; and for a girder of uniform depth and uniform strain per square inch, however loaded, the divisor will be 4.

The value of E varies considerably, even in the same length of rail or plate; but, as the result of many experiments, the author adopts the following average values:

For iron beams, E=.000085 to .00010.
For steel beams, E=.000075 to .00009.

At working strains the value approximates more nearly to the smaller, and at strains near the elastic limit to the larger figures.

In the case of built girders, the calcu-

lated and experimental results compare best when the depth d is taken between the flanges, and not from outside to outside; and where the web is thin the value of E may be taken at .00012. Although the author has on several occasions tested built girders beyond the elastic limit, without detecting the slightest movement of rivets and plates, it is only reasonable to conclude that the riveted structure must be a trifle less rigid than a solid beam.

The variation in the value of the modulus is a matter which has not yet received sufficient consideration from engineers. In built girders the practical effect of this variation no doubt is, that whilst a uniform strain, say of 5 tons per square inch, is assumed to be acting on the flange, the real strain on the several plates may range almost from 4 tons to 6 tons per square inch. Mr. Bender, and other American engineers, have found the moduli of eye bars to vary considerably with the cross section;* and other experiments also indicate the advisability of building up the flanges of girders with plates of uniform size, as well as quality.

Although, on the average, a steel rail or beam will be found stiffer than an iron one of the same cross section, this will not be true of every individual specimen. Thus, in some recent experiments, conducted for the author by Professor Kennedy, M. Inst. C.E., the moduli determind with great exactness for one piece of steel, and two pieces of iron rail of the same cross section proved at low strains to be respectively .000086, .000078, and .000089.

Frequent reference has been made to the terms "elastic limit" and "permanent set;" and it is necessary to explain what is understood by those expressions in the present paper.

If deflections or extensions be noted in a microscopic manner, permanent set will be apparent under comparatively low strains; but if the sets are plotted as ordinates to a curve, it will be found that, at a certain point more or less defined, the curve sharpens in radius, and in some cases diverges almost at right angles. The occurrence of this curve of course marks the attainment of the elastic limit; but different observers would only by chance agree as to the exact point of commencement, and hence the differences which often arise as to the elastic limit. In the case of hardened steel the curvature is very gentle; in that of soft iron, a sudden flow of metal often makes the bend almost rectangular. In cases where there is doubt as to the fair position of the limit, the author draws tangents to the deflection curve at points corresponding respectively to, say 40 per cent. and 60 per cent. of the estimated ultimate load, and takes the intersection of those tangents as marking the position. Except in the case of hardened steel, the elastic resistance considered in this broad practical sense will be generally found, both in iron and steel, to be equal to from 50 to 55 per cent. of the ultimate tensile resistance of the material.

In conclusion, the author would remark that the experiments detailed in this paper are but unselected samples of many hundreds, in which the same accord between calculated and experimental results is exhibited.

A word of caution is necessary to students: firstly, that differences of 4 or 5 per cent. between calculated and experimental results are suggestive of nothing, because different pieces of rail rolled from the same bloom or ingot exhibit that variation; and secondly, that in investigations of this sort it is absolutely essential to reject all tests made by unskilled persons. A single example will suffice: an iron rail which the author calculated would exhibit an elastic strength at 5-feet bearings of 9.5 tons, and a practical ultimate strength of about 19 tons, was returned, firstly by the manufacturers, and afterwards by the author's inspector, as exhibiting the strength and deflection set forth in the first line of the following table, whereas the true experimental results were those given in the second line:

Deflection Inches	$\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$	3	4	$4\frac{5}{8}$
Weight in tons.	14	24	34	40	43	48
	9.3	14.7	16.0	16.8	17.6	19 0

The results of the first line were con-

* Trans. American Society of Civil Engineers, vol. v. (1876), p. 147. "Continuous Girders," by C. Bender.

firmed by further experiments after the attention of the manufacturers and inspector had been called to the matter, and they adhered to their returns in perfect good faith.

By following the method of calculation indicated in this paper, the author, during the past fifteen years, has found no difficulty in specifying the strength which a rail should exhibit under the lever test, when made of steel or iron of the desired tensile strength; and much time and labor have been saved in dispensing with the planning out and testing of pieces under direct pull.

At the same time it is a practical convenience to be enabled to specify with exactness the tests for a new and untried section of rail. Thus, a few months ago (the fact is worthy of record for more reasons than one), a contractor offered to substitute steel for iron, without extra charge, in some 5,000 tons of flange rails he was delivering; and, as the rails had holes in the flanges, the author especially desired to secure steel of uniform and relatively soft quality. He specified, therefore, that the rails, when loaded with a weight of 20 tons at the center of 3 feet 6 inches span, should exhibit a permanent set not less than $\frac{1}{32}$ inch, nor more than $\frac{8}{32}$ inch. The test was arrived at as follows: the moment of resistance of the 70-lbs. rail was 8.75; the ratio of increased tensile strength under transverse stress 1.22; and, as the desired maximum direct tensile strength of the steel was 37 tons, with an elastic limit of 53 per cent., the maximum elastic transverse strength, at 42-inches bearings, would be

$$\frac{37 \text{ tons} \times 1.22 \times 53 \text{ per cent.} \times 8.75 \times 4}{42 \text{ inches}} = 19.9 \text{ tons.}$$

A set of at least $\frac{1}{32}$ inch under a load of 20 tons would, therefore, ensure the steel being not more than 37 tons per square inch in tensile strength. But it was also necessary to define a test for the lower limit of its strength, fixed at 33 tons per square inch. Under the load of 20 tons the strain upon steel of this strength would be the following percentage of the ultimate strength:

$$\frac{20 \text{ tons} \times 42 \text{ inches}}{33 \text{ tons} \times 1.22 \times 8.75 \times 4} = 60 \text{ per cent.}$$

Now the author knew from previous experiments that, within certain limits, a rail at 42-inches bearings takes a set of about $\frac{1}{32}$ inch for each 1 per cent. strain beyond the elastic limit; hence, as the elastic limit in the above instance is assumed to be at 53 per cent., the set at 60 per cent. would be about $\frac{7}{32}$ inch, or say $\frac{1}{4}$ inch. The specified sets of $\frac{1}{32}$ inch to $\frac{1}{4}$ inch would, therefore, correspond to steel having a direct tensile strength not less than 33 tons, nor more than 37 tons. It only remains to add, that the rails as manufactured complied with these tests, and that the direct tensile strength of a strip planed from the bottom flange of one of the stiffest specimens was 36.7 tons per square inch

As regards the possibility of substituting for the practical experience now indispensable in a designer, a general theory of transverse strength, universally applicable and wholly satisfactory from a scientific point of view, the author is not at all sanguine. A careful observation of the behavior of structures of every class under stress has satisfied him that sooner or latter, in every instance, a stage in the investigation is arrived at where the general theory becomes valuless, and even dangerous, except in the hands of the experienced engineer. At the same time the purport of this paper will be entirely misconceived if it is understood to reflect in any way upon the importance of direct experiment and strict mathematical investigation, of the value of which no one can be more alive than the author.

Herr Bottger has recently described a metallurgical use for glucose, and says that there is no method for reducing the salts of silver so convenient and so sure as that by glucose in alkaline solution. Take, for example, chloride of silver freshly precipitated and well washed, suspend it in a sufficient quantity of diluted caustic soda, and add a small portion of glucose; in a few minutes, upon boiling, the reduction takes place. The silver can be collected, washed and slightly calcined, in order to obtain the metal pure, under the form of a light sponge of a dull white. The same method furnishes an exceedingly active platinum black.

THE AREA OF THE SQUARE DEGREE

By FRANK D. Y. CARPENTER, C. E.

Coutributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN finding the area of a large portion of the earth's surface, as, for example, the territory of the United States, it is best to consider this surface as an aggregation of quadrilaterals bounded by meridians and parallels, the extent of each of which is one degree in latitude by one degree in longitude. Each of these blocks may be called, for the sake of convenience, a "square degree." All of these square degrees lying in an east and west series across the country have the same area. It is, therefore, only necessary to determine the contents of a tier extending north and south between the extreme latitudinal limits of the country which is to be treated.

If the earth were a perfect sphere it would be an easy matter to find the area of the square degree.

The area of the sphere is represented by the formula

$$4\pi R^2.$$

Of the spherical zone, being derived from that of the sphere,

$$4\pi R^2 \sin.\tfrac{1}{2}(L'-L)\cos.\tfrac{1}{2}(L'+L)$$

And of the spherical quadrilateral, being a definite portion of the zone,

$$\frac{\pi}{90}(M'-M)R^2\sin\tfrac{1}{2}(L'-L)\cos\tfrac{1}{2}(L'+L),$$

in which R is the radius of the sphere, and M', M, and L', L, are the boundary meridians and parallels of the quadrilateral.

To adapt this formula for the spherical quadrilateral to the spheroidal surface of the earth some geographers, accustomed to the frequent substitution of the normal for the radius in their geodetic and astronomical operations, have attempted to make the normal for the mean latitude, $\frac{L'+L}{2}$, do the same duty in this case. This application is erroneous, and it is to demonstrate its falsity and to provide a correct formula, that this note is prepared.

To find, then, the contents of a square degree upon the earth's surface, the following course may be pursued:

Take the length in meters or yards of the radius of curvature of the meridian, Rm, at the middle latitude $\frac{L'+L}{2}$, of this area, and consider it as the radius of a new and perfect reference sphere, to whose conditions this square degree shall be adapted, and by whose formula its area shall be determined. From the meridional arcs to be found in all geodetic tables take the latitudinal extent, $L'-L$, of the square degree under consideration; also, from the radius of the reference sphere, compute its circumference and thence the length of one degree of latitude, which, since this is a perfect sphere, will be $\frac{1}{360}$ of the great circle. It will be found that these degrees of latitude on sphere and spheroid are practically equal.

Now take the extent in longitude of the square degree, measured in meters along its middle parallel, and apply it along the same parallel of the reference sphere. It will be found to exceed a degree in length upon the latter, for the circumference of any parallel upon the earth's surface is a function of the radius of this parallel, and this radius is found by the formula

$$Rp = N\cos.L,$$

while, upon the reference sphere,

$$Rp = R\cos.L.$$

But R is the radius of curvature of the earth's meridian, and this is constantly smaller than the normal for the same latitude. Therefore, one of the earth's parallels is larger than the corresponding parallel on the reference sphere, and, in proportion, one of the earth's degrees of longitude is longer than a corresponding degree on the same. It is for this reason that the formula for the sphere cannot be adapted to the spheroid by the substitution of the radius of curvature for the radius, a step which, at first glance, might seem feasible.

A square degree upon the earth is thus shown to be equal to an extent of one degree in latitude by one degree and

some seconds in longitude on the new sphere, and, with these data and the radius of this sphere, its area can be now determined by the formula for the spherical quadrilateral.

In this method the earth's meridian, as far as included, is supposed to have the constant curvature of its middle point; it may therefore be advisable, to avoid error, to restrict this solution to areas not exceeding a square degree in extent.

To illustrate the preceding process, let us take any square degree lying between parallels 37° and 38° of latitude.

The radius of curvature of the earths' meridian for the middle latitude 37° 30′ is 6358420 meters.

The length of a degree upon a reference sphere with this distance as a radius is 110975.4 meters. The length of meridional arc from 37° to 38° latitude on the earth is 110975 meters. Observe the agreement. It is to be expected, however, when it is remembered that a degree of latitude upon the earth is a length of arc limited, not by two radii, but by two normals which intersect at the approximate center of curvature of the arc, and hence at a distance from the surface equal to the radius of curvature.

The length of a degree of longitude measured along parallel 37° 30′ on the earth is 88420 meters. The same, on parallel 37° 30′ of the new sphere, is 88042.7 meters. That is, one degree upon the earth equals 1° 00′ 15″.43 or 1°.004285 on the reference sphere.

A quadrilateral of 1° in latitude by 1°.004285 in longitude between parallels 37° and 38° of a sphere whose radius is 6358420 meters, comprises an extent of 3788.55 square miles. This is the area of the square degree aforesaid. Calculated by the current but erroneous formula, it would be 3804.49 square miles. The error of the latter, as will be seen, is 15.94 square miles, and, continued in the same proportion throughout the United States it would give a result wrong by many thousands of square miles. It will be interesting to note, in the revised areas about to be published as one of the results of the tenth census, how serious a misconception we have hitherto had upon this subject.

It now remains for us to arrange the results of this discussion in the concise shape of a formula. To do this it is only necessary to find some expression for the value of a degree of the earth's longitude in terms of corresponding degrees upon the reference sphere.

The length of a degree upon the earth is

$$\tfrac{1}{360}.\ 2\pi N.\ \cos.\ L.$$

On the new sphere it is

$$\tfrac{1}{360}.\ 2\pi Rm\ \cos.\ L.$$

Therefore one degree on the spheroid is equal to $\frac{N}{Rm}$ degrees on the sphere, and $M'-M$ degrees on the former equal $(M'-M)\frac{N}{Rm}$ degrees on the latter. Substituting now in the formula for the spherical quadrilateral, we have, for the area of a similar figure on the spheroid,

$$\frac{\pi}{90}(M'-M)\frac{N}{Rm}.Rm^2.\ \sin.\tfrac{1}{2}(L'-L)\cos.\tfrac{1}{2}(L'+L)$$

Or,

$$\frac{\pi}{90}(M'-M)N.Rm.\sin.\tfrac{1}{2}(L'-L)\ \cos.\tfrac{1}{2}(L'+L).$$

That is, for the square of the radius of the sphere we substitute the product of the radius of curvature of the meridian by the normal, which is the radius of curvature of the great circle perpendicular to the meridian, these two radii being taken at the middle latitude of the area to be treated.

The foregoing is an illustration of the extra labor and annoyance imposed upon the mathematician by what he comes at last to consider as the imperfect manner in which the universe is put together. If the earth were only a perfect sphere; if the pole star were really at the pole; if the magnetic needle pointed to the north, or, indeed, were constant in any direction; if the earth's axis were perpendicular to its orbit plane; if the moon were more straightforward in her course and the sun less irregular in his comings and goings; if the stars were placed in regular order instead of being sown broadcast; and if the famed circle of heavenly motion did not so often degenerate into an ellipse, the laborious processes of astronomical and geographical computation would be very much simplified, certainty would take the place of approximation in their results, and they would become exact sciences indeed.

ON PIN CONNECTIONS FOR IRON BRIDGES.

By Dr. E. WINKLER.

Translated from the "Deutsche Bauzeitung" of August 14, 1880, by G. F. Swain, S. B.

THE chief advantage of the system of pin connections for iron bridges, almost universally used now in America, is claimed to be the possibility of a more exact determination of the stress in each piece, and partly in a reduction of the stress itself. It is, however, frequently forgotten that the hinges are never perfect, that is, that they never permit an absolutely unhindered rotation, on account of the fact that a tendency to rotation calls into play the friction of the pin, the effect of which increases with the size of the pin. Nevertheless, very large pins have sometimes been projected; for example, one of the projects submitted for the Schinkel competition of the Society of Engineers and Architects of Berlin in 1879, provided for pins in the upper chord over 28 inches in diameter (.72 meters); and in the *Journal of the Austrian Society of Engineers and Architects* for 1880, p. 127, is published a project in which some of the lower chord pins are equal in diameter to the height of the chord.

In order to examine this point, let us first ask what diameter the pin must at least have, in order that a rotation may be just prevented, so that in this case the pin connection acts exactly as a riveted one would.

If ρ is the radius of curvature of the originally straight axis of a girder, M the moment acting in any cross section, E the coefficient of elasticity, I the moment of inertia of the whole section about its neutral axis, then if we neglect the influence of the deformation of the web members we have, as is well known,

$$\frac{1}{\rho}=\frac{\mathrm{M}}{\mathrm{EI}}.$$

The effect of the deformation of the web members is to increase this value by an amount which may be nearly 40%, and we will therefore put

$$\frac{1}{\rho}=a\,\frac{\mathrm{M}}{\mathrm{EI}} \quad . \quad . \quad . \quad . \quad . \quad (1);$$

a being a coefficient greater than 1. A more exact investigation could easily be made, but we prefer at present the above approximate formula.

If m denotes the moment which acts on one of the chords itself (causing it to bend between two joints), and i the moment of inerta of the chord section, then we shall also have (the joints being supposed incapable of permitting a rotation)

$$\frac{1}{\rho}=\frac{m}{\mathrm{E}i}\ ;\ m=\frac{\mathrm{E}i}{\rho},$$

and substituting the value of ρ from (1)

$$m=\frac{ai}{\mathrm{I}}\,\mathrm{M} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If S is the stress in the chord considered, h the height of the girder, then in general we have approximately, and exactly in the case of straight chords $\mathrm{M}=\mathrm{S}h$, and hence

$$m=\frac{ai}{\mathrm{I}}\,\mathrm{S}h \quad . \quad . \quad . \quad . \quad (3)$$

The pressure of the chord on the pin is also S. Hence if f is the coefficient of sliding friction, and d the diameter of the pin, the friction will cause a moment equal to m, or will balance m, when $m=\mathrm{S}f\frac{d}{2}$. Hence we must put, in order to find the necessary diameter of pin,

$$\frac{ai}{\mathrm{I}}\,\mathrm{S}h=\mathrm{S}f\frac{d}{2}$$

and

$$d=\frac{2aih}{\mathrm{I}f} \quad . \quad . \quad . \quad . \quad (4)$$

If F is the cross section of the chord, and r its radius of gyration, we have

$$\mathrm{I}=\tfrac{1}{2}\mathrm{F}h^2\ :\ i=\mathrm{F}r^2$$

hence

$$d=\frac{4ar^2}{fh} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

If the section of the chord is a rectangle, as in the lower chords of American bridges, and if the breadth is b and the

height c, we have $F=bc$; $i=\frac{1}{12}bc^3$; $r^2=\frac{i}{F}=\frac{1}{12}c^2$, hence

$$d=\frac{ac^2}{3fh} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

If we assume $a=1.25$: $f=0.15$, we have

$$d=2,8\frac{c}{h}.\,c \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and even if the pins were lubricated, and f became as small as 0, 08, we should have

$$d=5,2\frac{c}{h}.\,c \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

As this diameter is always smaller than the diameter of the pins in use in America, we can conclude that the pin joints as a rule do not act like hinges at all. The most favorable chord section is the one with the largest moment of inertia, but even in the most favorable case r^2 is at most equal to $\frac{1}{6}c^2$, and hence d is twice as large as in the previous case. Even here it appears scarcely possible to make the pin so small that they shall not prevent rotation. The cross-shaped chord section, for which pin connections have very lately been used by Gerber, in Munich, appears still more unfavorable than the rectangular section.

If the diameter of the pin is made smaller than is necessary to insure equilibrium between the moment of the friction and m, a rotation will occur; but the bars will bend until a state of equilibrium between the two moments arises. If the diameter is made only $\frac{1}{n}$th of that determined by the previous investigation, there will still exist in the bars a bending moment equal to $\frac{1}{n}$ th of that which would exist were the connections riveted.

It may be assumed, probably, that in consequence of shocks and vibrations, a certain rotation will nevertheless occur, so that gradually a state of things comes to exist in which the separate bars, under the dead load alone, remain straight, and possess the stresses determined by the theory supposing the joints hinged. But this is not true as regards the live load.

In regard to the web members, the investigation is more difficult than in the case of the chords, which we have hitherto been considering. The equations (5) and (6) may be considered as approximate in this case, if r and c refer to the section of the web member. Hence the web members would generally require still smaller pins to connect them with the chords than the chords require for connection with each other.

ON THE USE OF ASPHALT AND MINERAL BITUMEN IN ENGINEERING.

By WILLIAM HENRY DELANO, Assoc. Inst. C.E.

From Minutes of Proceedings of the Institution of Civil Engineers.

I.

In the year 1876 the author translated for the Institution a memoir by M. Ernest Chabrier, civil engineer, "On the Applications of Asphalt." This paper, and the well-known work of M. Léon Malo on the same subject, are exhaustive as regards the general question.

The object of the present communication is to give a description of certain executed works, with their cost, an account of various failures that have been overcome, and such information concerning the quality and preparation of the material as will enable a supervising agent to insure good work and discover fraud. The author's personal experience is confined to France, particularly Paris, where he has been engaged since 1871 in the practical application of natural asphaltic compounds, and where the use of the material has obtained a position as one of the great industries of the country.

It is important that M. Malo's nomenclature should be adhered to in specifications. 1st. Asphalt is a natural pro-

duct, a bituminous limestone, consisting of carbonate of lime and mineral bitumen, intimately combined by natural agency. 2nd. Asphalt mastic is the rock ground to powder and mixed with a certain proportion of bitumen similar to that originally contained in the rock. 3rd. Gritted asphalt mastic is asphalt mastic to which washed or river sand, free from all earthy matters, has been added. 4th. Asphaltic or bituminous concrete is gritted asphalt mastic in a hot state, mixed with dry flint or other stone. 5th. Bitumen is a mineral product found in asphalt rock, in Trinidad and in other places. According to Boussingault, bitumen is composed of

Carbon	85	parts.
Hydrogen	12	"
Oxygen	3	"
	100	

It is therefore an oxygenated hydrocarburet. It is not gas tar, nor Stockholm tar, neither is it pitch from suets and fatty matters, or from shale or petroleum.

The asphalts that have come under the author's observation are those of Val de Travers, Seyssel, Sicily, Chieti in the Abruzzi, Auvergne, Lobsann, and Limmer. Analyses of various asphalts by M. Hervé Mangon and M. Durand-Claye, of the Laboratory of the Ecole des Ponts et Chaussées, Paris, are given in Appendix A.

The engineer who is specifying asphalt for roadways, footpaths, waterproof coatings for arches, vaults, casemates, &c., may test the material thus: A specimen of the rock, freed from all extraneous matter, having been pulverized as finely as possible should be dissolved in sulphuret of carbon, turpentine, ether, or benzine, placed in a glass vessel and stirred with a glass rod. A dark solution will result, from which will be precipitated the pulverized limestone. The solution of bitumen should then be poured off. The dissolvent speedily evaporates, leaving the constituent parts of the asphalt, each of which should be weighed, so as to determine the exact proportion. The bitumen should be heated in a lead bath and tested with a porcelain or Baumé thermometer to 428° Fahrenheit. There will be little loss by evaporation if the bitumen is good, but if bituminous oil is present the loss will be considerable. Gritted mastic should be heated to 450° Fahrenheit. The limestone should next be examined. If the powder is white, and soft to the touch, it is a good component part of asphalt, but if rough and dirty, on being tested with reagents, it will be found to contain iron pyrites, silicates, clay, &c. Some asphalts also are of a spongy or hygrometrical nature. Thus, as an analyses which merely gives so much bitumen and so much limestone may mislead, it is necessary to know the quality of the limestone and of the bitumen.

For a good compressed roadway, an asphalt composed of pure limestone and 9 to 10 per cent. of bitumen, non-evaporative at 428° Fahrenheit, is the most suitable. Asphalts containing much more than 10 per cent. of bitumen get soft in summer and wavy; those containing much less have not sufficient bind for heavy traffic, although asphalt containing 7 per cent. of bitumen, properly heated, does well for courtyards, as it sets hard when cold.

Asphaltic rocks, rich in bituminous matter, generally contain volatile oils. In the author's opinion it is not safe to specify any asphalts for roadways that have not withstood at least three cold winters and three hot summers.

Trinidad bitumen is now largely used to mix with asphalt powder for mastic. In the raw state it contains from 40 to 45 per cent. of dirt, and 35 per cent. of water. It is refined by mixing with it about one-third its weight of schist or shale-grease (*i. e.*, the pitch remaining after the lighting and lubricating oils have been exhaled in distillation), and heating the mixture for twenty hours, after which it is passed through a fine colander and decanted. The theory is that the shale grease and water are evaporated, the earthy matters precipitated, and the other extraneous matters screened out. There is always a residue, however, of about 20 per cent. of fine clay in purified Trinidad bitumen, and sometimes much more. In testing, the easiest way is to dissolve the bitumen in sulphuret of carbon, and to strain the solution through thick blotting paper, which retains and gives the proportion of the clay, which should not exceed 20

per cent.; afterwards using the evaporative test already described.

ROADWAYS OF COMPRESSED ASPHALT.

It may be taken for granted that the use of asphalt roadways is now approved in England. The various reports of Mr. William Haywood, M. Inst. C. E., are conclusive on this point. No roadway is perfect; but the author is of opinion that, for cities with heavy traffic, and where the gradients do not exceed 1 in 50, a well laid surface of compressed asphalt is near perfection. It is noiseless, does not vibrate, produces neither dust nor mud, is cheap and durable, easily repaired, and the old material can be used again. The best foundation is a bed of Portland cement concrete, 6 to 9 inches thick, with as little floating as possible, laid on a resisting subsoil. The surface of compressed asphalt powder should be from 2 to $2\frac{3}{8}$ inches thick. The present price of a compressed asphalt roadway per square meter is, in Paris, for ordinary traffic:

	Frs.	Cts.
Portland cement concrete, 6 inches thick	5	25
Compressed asphalt, Seyssel or Val de Travers, 2 inches thick......	14	15
	—	—
	19	40

or, say, about 13s. per square yard. But the distance from the mines influences the cost of the material.

The first asphalt roadway laid by the author was in the Rue d'Antin, Paris, in 1872. With the exception of a piece cut off for the New Opera avenue, it has stood perfectly well to the present time. It replaced a causeway of granite sets, and one-half the expense was paid by the landlords of the street. As the engineers of the city were only able to specify a layer of 4 inches of hydraulic lime concrete, the extra cost of laying the 2 additional inches of concrete and the Portland cement was paid by the Compagnie Générale des Asphaltes de France, who had contracted to maintain for six years the roadways and footpaths in compressed asphalt and mastic. On each side of the roadway were placed gutters of Belgian granite sets, 16 by 20 centimeters and 60 centimeters wide, with cement-mortar joints, and a fall towards the curb of 1 in 28. This was done by order of M. Alphand, Director of Works of Paris, who had noticed that the greasy water, which runs from the houses into the gutters, in streets where there are no drains, rotted the asphalt, and that the consequent repairs were difficult owing to the habit of flushing the gutters with pure water several times a day. This difficulty does not exist in streets where there are drains.

In laying the concrete, the screeds were set so that there should be a fall on each side of the crown of the roadway of 1 in 50. The average width of the roadway was 17.7 feet, and the longitudinal fall about 1 in 100. The asphalt powder was ground fine in a Carr's disintegrator, heated in a yard $1\frac{1}{2}$ miles distant to 284° Fahr., carefully spread over the dry concrete, and rammed with hot rammers till the surface became resonant.

Appendix B gives a tabulated statement of the works executed by the author, with the nature of foundations, and observations as to duration.

Among the difficulties the contractor has to contend with in laying an asphalt causeway are the prejudices of the foremen, who prefer tradition to reason. The tradition is that sand is incompressible; that sand makes a good foundation for granite sets, and therefore does equally well for concrete. Sand is incompressible in a cylinder, but under street traffic gets displaced, and absorbs water, causing the concrete to crack. The layer of compressed asphalt follows, and then unsatisfactory repairs are made, for repairs on a shifting concrete, through which the wet can rise, never last long. The author, when executing such repairs in winter, had the surface sprinkled with dry cement, afterwards rammed, and then a layer of liquid asphalt run over it and allowed to cool, so as to have a dry surface on which to lay the hot powder.

When superseding granite sets by asphalt, the sand should be removed, and the concrete laid on the hard soil; for, just as hard granite sets require an elastic foundation, so does the slightly elastic surface of compressed asphalt require a rigid foundation. In preparing the foundation of the asphalt roadways of the Place de l'Europe and the Auteuil bridges, Paris, a coating of liquid asphalt $\frac{3}{8}$ inch thick was first laid down to

keep out the surface water from the masonry, then a 3-inch bed of sand by order of the Government engineer, who feared lest the immediate contact of the rough concrete with the asphalt mastic would damage this coating. On the top of the sand was put a layer of 4 inches of hydraulic lime concrete, and on the top of the concrete 2 inches of compressed Val de Travers asphalt. The contracting company had agreed to keep these roadways in order during six years for one franc per square meter per annum. The cost to the contractors was about ten francs per squares meter per annum. The rain water filtered through the curbstone into the layer of sand; in hard winters it froze, and forced up the concrete, and in summer the sand yielded under heavy traffic, causing depressions in the surface. The author, finding the contract most onerous, proposed to the engineers of the city of Paris to lay the whole work afresh upon their paying only for one-half of the new concrete, and using up the sand for mortar. This offer was refused. Since the termination of the six years' contract the two bridges have been in worse order than ever; that at Auteuil is now nearly all macadam on one side; the Pont de l'Europe is honeycombed also in holes and lumps.

Experience has proved that hydraulic lime concretes are of little use for asphalted roadways; they do not set quickly enough for crowded cities, and are never dry, as is shown by the fact that, whenever an opening is made to a gas or a water pipe, the old lime concrete is found to be wet. In 1877 the author laid the Pont Masséna, Paris, a railway viaduct, for M. Barabant, municipal engineer; but on the liquid asphalt coating, Portland cement concrete 9 inches thick was laid, and on the concrete a layer of 2¼ inches of Val de Travers compressed asphalt. This work has never moved, and may last from fifteen to twenty years, in spite of heavy goods traffic. In 1872 the author inherited a ten years' contract for the maintenance of the asphalt roadway of Elbeuf bridge, covering 1,400 superficial meters. This structure is of wrought iron, subjected to considerable vibration under traffic. The flooring is of Mallet's buckle-plates, covered with hydraulic lime concrete, with a layer of 2 inches of compressed asphalt superposed. Owing to the shape of the buckle-plates the concrete was of unequal thickness. The maintenance of the roadway under these conditions cost 10,000 francs per annum, whilst the sum paid by the Department of the Seine Inférieure was 1,400 francs, or one franc per square meter per annum. The lime concrete broke up under the vibration, and the asphalt of course followed. As the repairs were continuous, application was made to the authorities to be relieved of the contract upon payment of an indemnity. The authorities declined. They had tried wood, which wore out; granite sets were too heavy; macadam was too expensive. To meet the difficulty of the vibration, it was resolved to replace the hydraulic lime concrete with bituminous or asphaltic concrete. The roadway was accordingly taken up, the old compressed asphalt was heated till it fell to powder; it was then mixed with refined bitumen to make it into mastic, to which 40 per cent. of dry grit was added, and with every 2 parts of this asphaltic mortar, 3 of hot flint stone were mixed. This concrete was laid down hot upon the buckle plates, and well rammed and dressed till a hard and slightly elastic surface was obtained. Upon this surface a layer 2 inches thick of compressed Val de Travers asphalt was put down. This work was finished in October, 1875. Up to August, 1879, not a single repair had made, though the traffic had much increased. In the Rue de Sèvres, in 1876, the author replaced a roadway of granite sets by compressed asphalt, in front of the Hospital Necker and the Institution of the Infant Blind, and resolved to replace the hydraulic lime concrete specified by natural or Roman cements. The result was not satisfactory; the concrete crumbled under the heavy traffic, and a portion of the work had to be relaid.

From the foregoing it appears that, for asphalt, good foundations of Portland cement concrete must be laid not less than 6 inches thick, but a layer of 9 inches is better. Lime and Roman cement concretes should never be specified for heavy traffic. Bituminous concrete cost, say, £4 per cubic yard, and is too expensive for ordinary work, though

invaluable in special cases. There is some difficulty in getting thoroughly burnt and finely ground Portland cement. Fraudulent mixing is practised, and marked casks are refilled with an inferior article.

The asphalt powder cannot be too fine. If it could be got like the stive dust in flour mills, or, as the French workmen say, "folle farine," it would be perfection. In heating it care must be taken to evaporate all the volatile bituminous oils. To this end the powder heaters should be open at each extremity and the powder well stirred. Great care must be taken that no wood, or foreign object, gets mixed with the powder, as it will cause a hole sooner or later. Sometimes, after three or four years, a chip of hard wood will work its way up through a layer of 2½ inches of asphalt under traffic. The author in 1876 laid down a road in the Rue de Vaugirard with great care; a month afterwards there was a hole in the middle. Upon examination it was found that one of the workmen had left in the concrete his wooden screed, which had rotted. Mr. Edwin Chadwick, C. B., who has studied asphalt under the hygienic aspect, has designed an asphalt tramway for ordinary carriages, which should answer well, as asphalt properly laid is more durable than granite flags or iron rails.

Asphalt is not slippery *per se*, but it becomes so if a coating of greasy mud is allowed to remain upon it. Roadways of asphalt, from the same mines as used in London, are laid in Paris, and the complaint of slipperiness does not arise. This immunity is not the result of a drier atmosphere, as some have supposed, but simply that in the latter city the roadways are regularly swept and washed, whereas in London they are not.

The dampness of the atmosphere has an important bearing upon the question of the best material for carriageways in towns, and the author has been at some pains to obtain trustworthy information on this subject. He hopes to establish the fact, that the alleged greater dampness of the air in London against that of Paris is to some extent imaginary, and that it is to want of scavenging alone that the slipperiness of asphalt roadways in London is attributable. By the kindness of M. Mascart, director of the Bureau Central Météorologique, he is able to give authentic figures showing the humidity in Paris for six years ending 1878. The values of London are taken from the quarterly returns of the meteorology of England, published by authority of the Registrar-General.

Table of Seasonal Humidity.

Saturation = 100.

Paris (Saint Maur).	1873.	1874.	1875.	1876.	1877.	1878.
Winter.	86.6	88.5	87.6	89.5	86.2	88.3
Spring......	75.0	71.8	66.4	69.9	76.8	77.0
Summer	78.7	67.8	77.3	69.6	75.1	78.7
Autumn. ...	87.3	85.1	85.0	87.9	83.7	85.6
Means.....	81.9	78.3	79.1	79.2	80.4	82.4

London (Greenwich).	1873.	1874.	1875*	1876.	1877.	1878.
Jan—March	86.0	84.0	80.0	85.0	83.0	84.0
April—June.	78.0	76.0	88.0	75.0	73.0	79.0
July—Sept ..	77.0	77.0	81.0	74.0	76.0	79.0
Oct.—Dec...	88.0	88.0	85.0	83.0	84.0	85.0
Means.....	82.2	81.25	84.6	79.2	79.0	81.75

The means for the six years are, therefore, for Paris, 80.2; London, 81.5—a difference of dampness insufficient to exercise any appreciable influence.

In a paper published in the "Annales des Ponts et Chaussées,"† M. Vaissière, Chief Engineer, gives the total cost of the scavenging service in Paris as £195,000 per annum. This includes scraping, sweeping, and washing the streets, watering in summer, and clearing away ordinary snowfalls in winter. The author has not access to the London Vestries, but he doubts if in the aggregate they spend much less in order to obtain a result which in comparison is wholly inadequate. In any case, in view of the advantages to the senses and health of the inhabitants, and the immense saving in the money value of goods now spoilt by mud and dust, he ventures to assert that an efficient system of scavenging similar to that of

* Heavy rain-storms in Spring and Summer.

† *Vide* Minutes of Proceedings Inst. C.E., vol. 1, p. 223.

Paris would be cheaply obtained if its adoption cost five times the amount quoted above.

In asphalted streets, where no provision exists for washing the roadways by flushing from the hydrants, an arrangement has been devised which is found to be economical and easy of application. The apparatus consists of a wrought-iron or wooden cart-body, mounted on four wheels, of which the two front ones swivel freely, and are drawn by two stout horses. Under the shaft runs a jointed pipe, with a perforated delivery tube, set at right angles, and which can be raised or lowered by means of a rack. This delivers a shower of water in front of the horses, which help by their tread to liquify the mud. The plan is adopted in Piacenza and other towns of Northern Italy, and is attended with no inconvenience to the horses, or otherwise. Behind the horses is a second distributor, which further dilutes the sticky mud, followed by an adjustable broom. Behind the broom is a third delivery pipe, followed by an adjustable revolving cylinder, set obliquely, and carrying a combination of bass brooms and "squeegees." The oblique set causes the diluted mud to be at once swept into the gutter. The capacity of the cart is 600 gallons, the three pipes distribute together two gallons per second, but this quantity can be regulated according to the state of the mud. Supposing the horses to walk at the rate of 6 feet per second, the tank will be emptied in five minutes.

The cost of this apparatus complete is taken at £70.

	£	*s.*	*d.*
The interest and maintenance at 15 per cent. per annum would be per day	0	0	7
Wages of two men at 4s.	0	8	0
Two horses and harness	1	0	0
Total per day	1	9	7

Or say for two machines, £3 per day.

Adopting the figures given in Sir Joseph Whitworth's paper on street cleansing:*

	£	*s.*	*d.*
One machine would do the work of 17 men (sweepers) at 4s. per day	3	8	0
Cart horse and driver	0	16	0
Total per day	4	4	0

* *Vide* Minutes of Proceedings Inst. C.E., vol. vi., p. 431.

Or for two sets £8 8s., as against £3 for the two washing and sweeping machines. Further, taking Sir Joseph Whitworth's estimate of 14,000 square yards per day, the then cost of cleansing a length of street of 60 yards, and, say 20 yards wide, would be 2s. 7d.; but it is fair to assume that a greater surface of smooth asphalt could be cleansed in the same time than of ordinary macadam.

The scavenging of Paris costs 2½s. per square meter per annum, or say 2d. per square yard. A comparison between the two asphalted streets of Rue de Richelieu in Paris, and Cheapside, London, in muddy weather, shows the advantage of the Paris system of scavenging. Horses in Paris slip on the hard granite sets; they do not slip on asphalt more than on macadam, and on a level road start easily when loaded.

Compressed asphalt is not affected by heat, except that it becomes slightly soft, but without losing its ring under the horses' hoofs, and extreme frost has no effect upon it; but in case of any cracks or holes they will get gradually enlarged under the action of repeated wet thaws. It is easy to clear snow off asphalt, much more so than off any other paving.

The author has used asphalt bricks and cubes for paving; but even under the most favorable circumstances the employment of powder is preferable. It is not easy to effect repairs in asphalt sets from the fact that, when under traffic, compression is going on, and the new sets, not having the same density as the old, rise above them and so get chipped.

Compressed asphalt gives no spark when struck, which makes it valuable for the floors of powder magazines, cartridge manufactories, &c. The French Artillery have used it for this purpose at the School of Pyrotechny at Bourges, and at the Donjon of Vincennes, and the Military Engineers have employed it at the fort of Génicourt, near Verdun.

Compressed asphalt is used in gateways like those of the Place du Carrousel, and the Place des Vosges, Paris, to absorb vibration and thus to prevent the destruction of architectural ornaments, &c.

The extent of surface of compressed

asphalt in the public streets of Paris is 309,000 square meters—or 370,000 square yards—not taking into account the numerous courtyards, gateways, and passages for private use.

QUALITIES OF VARIOUS ASPHALTS.

With regard to the quality of the various asphaltic rocks, the author submits the following opinion: Val de Travers rock is sure to give a satisfactory result if properly ground, heated, and laid on a good foundation. It is, however, sometimes too rich in bitumen, in which case it must be heated longer and well stirred, to get rid of the volatile bituminous oils. An admixture of 25 per cent. of old Val de Travers compressed asphalt, cleaned, grnund up and passed through the pulverizing machine simultaneously with the new rock, so as to get thoroughly mixed, is of advantage with rich asphalt; but it is not advisable to mix two asphalts from different mines, as for instance, Val de Travers and Seyssel. Such mixtures will last for two, three, or even four years, and then break up, at least this has been the author's experience in the Rue de Richelieu. Seyssel rock contains less bitumen than Val de Travers, and the limestone being harder and of finer grain is frequently unimpregnated; for these reasons Seyssel rock should be broken in pieces and hand-picked before grinding. The author has laid many streets in Paris in Seyssel asphalt, and always uses it for courtyards. In spite of the comparatively small proportion of bitumen, this rock will bear a good heating. The bitumen is not of an easily evaporative character. Sicilian rock, from Ragusa, is a coarse-grained spongy limestone of unequal impregnation. The bitumen is of a very volatile character. This rock is no longer included in the list of those specified by the Paris engineers. Auvergne rock contains a large proportion of excellent bitumen, but the impregnated stone is more of a grit, or sandstone, than limestone. A trial was made in the Rue du Faubourg Poissonniere, in the year 1877, and the road lasted just three months. The asphalt was compressed cold with a 30-ton steam roller, having been previously sprinkled with volatile shale oil. Auvergne mastic is coarse and sets soft. Maestu rock has been used successfully for mastic, but utterly failed when laid in 1871 in London, in the shape of bricks compressed cold. Chieti rock is exceedingly rich in good bitumen, but has not been successfully used for compressed purposes in France. It makes very coarse mastic. Lobsann rock is of a mixed character, containing a large proportion of good bitumen and bituminous oils. It has been used exclusively in Paris since January, 1878. The winter of 1878–9 was eminently unfavorable to this rock. Some new work, laid on cement foundations, and where there is little traffic, has stood fairly, but time is required to test it. If it breaks up within three years it is of little use as a contractor's material. In Paris this rock, owing to its richness in bitumen, is mixed with one-third poor asphaltic rock ground fine.

MASTIC ASPHALT.

The surface of footpaths in mastic asphalt in Paris alone, is 3,150,000 square meters—or nearly 4,000,000 square yards; and when the courtyards, cellars, &c., are counted it is considered that double the surface exists.

The Paris engineers have made it a rule that the thickness of the layer of gritted mastic should be 15 millimeters, or $\frac{5}{8}$ inch, and a lime concrete 10 centimeters, or 4 inches thick, of which 2 centimeters, or $\frac{15}{16}$ inch, are mortar floated to keep the surface level. One fifteenth part has to be laid fresh annually. The contractor is paid for this and all the repairs besides (*i. e.*, to keep the work in order) a fixed sum of 35 centimes per meter, or $2\frac{1}{5}$d. per square yard per annum; the openings for gas and water pipes being paid for separately. Each system must be judged by its result. In Lyons, and in other towns of France, where repairs are paid for by the square meter, and the thickness of the asphaltic layer is $\frac{13}{16}$ inch, the work is well done, whereas in Paris the footpaths seldom look well. In fact, the engineer, knowing that a fresh fifteenth has to be laid every year, thinks that he will comprise therein all the bad work; and the contractor does not care to do good work because he may in the following year have to relay the new work as fifteenth part, owing to changes

of level, &c. Again, in this system of a limited sum paid per yard per annum for an unlimited quantity of repairs, one of the contracting parties must get an unfair advantage.

CONCRETE FOR FOOTPATHS.

In the author's opinion, a layer of four inches of hydraulic lime concrete on a firm soil is a good foundation for mastic asphalt; or for the same purpose 3 inches of Portland cement concrete may be employed. Roman cement should never be used in concretes for mastic asphalt, nor stone lime. Both cause bubbles and blisters, which eventually produce holes. Mortar floating should be used sparingly to fill up interstices in the concrete, and to form a level surface, and should be spread before the concrete is dry. A thick layer of mortar serves to cover bad concrete, but not to make a good foundation. One of the chief causes of cracks and depressions in the compressed asphalt roadways of Paris is from spreading a thick layer of mortar over the concrete, which crumbles under the traffic, and indeed under the iron rammers during the compression of the powder. A favorite fraud of the dishonest contractor is to cheat in the thickness of the concrete, nor does he neglect to carry out the same idea with the asphalt. In 1872 the author found a considerable portion of the concrete of the Rue de Richelieu $2\frac{3}{4}$ to 3 inches thick, instead of 4 inches, and the subsoil loose (the work had been let out to the workmen by the piece), whilst some footpaths in front of the Hotel de Ville were not laid with concrete at all, but a little mortar had been spread on the bare earth. Asphalt in itself has no more power of resistance to vertical pressure than sheet lead or india-rubber; therefore it must yield unless well supported from beneath.

MANUFACTURE OF ASPHALT MASTIC.

The rock must be ground into fine powder, all coarse grains being sifted out, returned to the disintegrator and reground. After being mixed with the bitumen, as described, it must be well worked, *i. e.*, the bitumen must be thoroughly incorporated with the asphalt, and an amalgam made capable of being ground again into powder. The quantity of bitumen to be added depends upon the amount contained in the rock, but 15 per cent. of the total weight is what mastic should hold when run in blocks. It is sufficiently tested when a wooden spatula can be put into the mass and withdrawn without adherence. Mastic made from fine-ground powder, when remelted, pure, or unmixed, spreads out under the wooden stave or spatula used by the asphalters for the covering of vaults, fillets, &c., and will absorb the maximum of grit when used for footpaths, stables, courtyards, &c.

MASTIC ASPHALT IN MILITARY ENGINEERING.

In the many large new forts constructed in France since 1871 pure mastic asphalt has been extensively used for covering the roofs of vaults, casemates, and powder magazines, with very satisfactory results; as when the inevitable settlements of the new masonary happens, the asphalt yields without cracking, whereas cement cracks and lets the water into the joints of the masonry, causing damp in the casemates and bad health to the garrison. The most recent practice is to lay pure mastic asphalt $\frac{5}{8}$ inch thick in two layers. When applied vertically for chimneys and air shafts a recess is cut in the masonry, into which the asphalt is run, so that the water passes over to the gutters or drains. The flooring of the casemates is laid with gritted mastic. The troops in garrison have sometimes complained of the asphalt flooring being damp. It is certain that it is non-absorbent, and therefore the condensed moisture remains visible and must be mopped up or swept away. The flooring of powder magazines is in pure mastic, over which, in some cases, wood planking, fastened with copper nails, is laid.

GROUTING FOR GRANITE SETS.

This work, which is charged in the Paris Architects' Price-book for sets, say 6 inches by 10 inches and 2 inches deep of mastic, costs about 2s. $11\frac{1}{2}$d. per superficial yard, whereas in gas tar and chalk the cost is only 1s. $8\frac{1}{2}$d. Mr. G. F. Deacon, M. Inst. C. E., has shown the inconvenience of using inferior materials for grouting. It is good policy to use natural asphalt mastic for this work. The interest on the increased cost is less

than the cost of renewels, to say nothing of the annoyance to traffic caused by frequent repairs. This grouting is particularly useful in courtyards and stables; it prevents the effluvium from all ordinary joints, which, with the subjacent layer of sand, soon become filled with horse-dung and other filth. It also holds the sets together, prevents the edges wearing, and lessons the noise whilst improving the appearance. Natural asphalt can be melted again and again with the admixture of fresh purified bitumen, without losing its qualities. In some grouting recently carried out in front of the terminal station of the Eastern railway in Paris, the joints are run too deep to keep the horse urine out, but it cannot percolate to the subsoil. Asphalt grouting should always be laid in dry weather, and the joints well rammed, so as not to use more mastic than necessary.

VERTICAL APPLICATION OF ASPHALT MASTIC.

This is a development of the fillet generally employed in all horizontal applications, and to keep out damp and moisture; the height is mostly 3½ feet to 4 feet. The price paid in Paris is about 4s. per superficial yard ⅛ inch thick. The mastic is pure, and is laid on in two layers, one workman following the other as closely as possible, using the mastic very hot and pressing it hard. The powder magazines in the Cherbourg forts have been recently so treated; also the chimneys and air shafts of the casemates of the Paris forts. The advantages of the employment of asphalt under such circumstances are that, should there be a settlement of the masonry, it does not crack like cement. In case of leakage, the removal of 40 feet of earth is costly, and as old cement cannot be used over again, it has to be carted away.

BITUMINOUS OR ASPHALT CONCRETE.

In 1872 the proprietor of a factory for painting on glass and china, threatened to take proceedings against the author for damages caused by the vibration of a Carr's disintegrator, running at 500 revolutions per minute, used in pulverizing asphalt in the factory of the compagnie Générale des Asphaltes. This vibration also interfered with the counting-house work of the Company's clerks, and, in fact, when the machine was running the ground shook within a radius of 25 yards. The old foundations in wood and masonry were therefore replaced by bituminous concrete, as were also the walls and the bottom of the pit on which the disintegrator works. This succeeded so well that it is now impossible to know from the vibration when the disintegrator is at work, and there have never been any yielding, settlement, or repairs, since it was laid. Subsequently, the author put down a foundation for a large steam press for stamping out iron frames, and striking twelve blows per minute. Also one at the Artillery Factory in the Donjon, at Vincennes, under the orders of Captain Naquet, for a small steam hammer, and for the factories of the Paris, Lyons, and Mediterranean railway, under the orders of the Engineer-in-chief Duboys, and other similar works. At the Paris Exhibition of 1878, a block of this material, weighing 45 tons, was used as a foundation for a Carr's disintegrator for grinding flour, running at 1,400 revolutions per minute.

IMITATION ASPHALT.

There are two kinds of imitation asphalt: 1st. A mixture of ground limestone, ground slate, and Trinidad bitumen, which, if properly made, is as dear, or dearer, than the real article, without being one-half as good. 2nd. A mixture of ground chalk, fire-clay, and gas tar, which is frequently passed off as real asphalt. The author's experience of this material is that it becomes soft in summer and cracks in winter, and should never be used for footpaths, or where there are great changes of temperature. The Paris engineers, after repeated trials on account of its cheapness, have proscribed its use. This mixture is readily recognized by its dull, black appearance, its characteristic smell, and the hard metallic sound it gives when struck against iron in cold weather. The unpopularity of asphalt with many engineers and architects arises from their having had work done with preparations of gas tar improperly called asphalt. Some contractors substitute shale grease or pitch from suets, or Stockholm tar, for bitumen. The result is a soft surface for the first year, which gives off

oils by evaporation, and breaks up after two or three years' wear; whereas asphalt properly laid on a good foundation will wear down evenly until little more than a film remains.

The tricks of the small Paris contractors are many. They keep a little natural asphalt and bitumen beside their boilers for show, all the while using gas tar and chalk, so that when the work breaks up the superintendent is frequently ready to affirm that asphalt was used, and declares for ever after that asphalt is of no use.

INGOT IRON.

From "The Engineer."

It has become so difficult to say what is the difference between Bessemer metal and wrought iron that for some time past engineers and metallurgists, alike, have freqently substitued the words "ingot iron" for "steel," and there can be no possible objection to the change in terminology; indeed, it is very much to be commended. The word "steel" ought to be confined to the product of the crucible or tbe cementing furnace, which always possesses characteristics which mark it out clearly and unmistakably from any form of iron. While, however, it is certain that ingot iron resembles very closely iron made in the puddling furnace instead of the converter or the open hearth, it is also certain that it possesses some characteristics which are very differcnt from any manifested by iron, and of these and of their nature it is essential that all makers and users of ingot iron should take note. Steel came to us after iron; and the qualities of steel are all estimated and pronounced good or bad by comparison with iron. Lowmoor, for example, and Bowling are taken as standards, and we hear it said a given steel is as "tough as Lowmoor," or that "it works like Bowling." In the course of years Lowmoor and Bowling—indeed, the best Yorkshire irons generally—have been brought up to a high degree of excellence, if excellence be supposed to consist in complying with the demands made by engineers for special qualities in the plates they work. Thus it has been found to be good practice to flange boiler plates, instead of using angle iron to connect them, and Lowmoor and Bowling plates have accordingly been made which will flange perfectly. Then steel plates were produced, with the same object in view, and with more or less success. Although it is convenient to call what has been for a long time known as "steel," ingot iron, and although it is also convenient to compare ingot iron with ordinary iron, we must not go too far, and assume that the two materials are practically the same for constructive purposes. On the contrary, there are very wide differences between them, and is just as well that these differences should not be overlooked even for a moment.

The great peculiarity about ingot iron is that for some reason, not yet understood, certain impurities affect it more than wrought iron; and that it is also very easy to set up in it intense initial strains, which never seem to exist in wrought iron. It is very well known that Lowmoor and Bowling plates are by no means absolutely perfect and it is probable that of late years the metal is not so good as it used to be. Be this as it may, plates from Yorkshire are now and then found to be very bad indeed. This fact is freely used by the advocates of steel. Thus, when a steel plate fails, they will ask, "Well, does an iron plate never give way?" This is a very good argument up to a certain point; but it must not be pushed too far. No one contends that the so-called perfect iron plates do not fail now and then; but a very little experience suffices to show that they do not fail in quite the same way as steel plates. It is not, in truth, the failures of ingot iron, but the manner of failure, which exerts the most malign influence on the future of the metal. To explain what we mean we may cite the case of a boiler-plate of steel which is flanged all round—say a back plate for a locomotive boiler. This plate is completed, put on one side for the night, and in the morning it is found that the flange has come away from the

plate everywhere. Here we have, in the first place, all the labor which has been expended on the plate wasted; but far worse than this, we have an element of doubt and uncertainty introduced which is prejudicial in the extreme to steel. If a plate leaves the flange while lying quietly in a yard, who is to say whether, should a second and similar plate be worked into a locomotive, it may not leave the flange when steam is up and with the most disastrous effect? This is a very serious question indeed for those who have much responsibility, as, for example, locomotive superintendents. It will be said, and truly said, that Lowmoor plates will now and then part company with a flange. We admit this; but there is no instance on record of Lowmoor giving way like steel. The defect in the Yorkshire iron would manifest itself almost from the first; and a crack would be found between the flange and the plate before the metal was cold. In one word, if wrought iron will bear the ordeal of being worked into shape, it may be relied on to support heavy strains. But when we come to deal with ingot iron there is apparently a risk that when work is complete it will, as in the case of the Livadia's boilers, tumble to pieces before it is put to use; or that having been put to use it will fail without a moment's warning. About the worst defect that Lowmoor or Bowling plates will manifest is a tendency to blister—very vexatious and annoying, but not very dangerous. Let us imagine that the Livadia's boilers had just withstood the 150 lbs. water test and had gone to sea; will any one, knowing what we now know concerning them, assert that the boilers would not have been more dangerous than if they had been made of good tough cast iron? To put this more plainly, the new shells are to be made, if they have not yet been made, of steel supplied by the Steel Company of Scotland. What is the security that this metal will be better than that which failed? Samples will bear specified tests; but so did the steel supplied by Messrs. Cammell. When we come to dive below the surface of things, it will be seen that there is no security at all that the new boilers will not behave like the old boilers, save the eminent reputation of the steel company of Scotland. But surely it must be admitted that this is a state of affairs quite without parallel as regards iron. Wrought iron has a reputation of its own; but steel at present, and possibly for a long time to come, has no reputation, and depends for its popularity as a constructive material on the reputation of those who make it. Let it not be forgotten that while both wrought iron and ingot iron are liable to fail, the characteristics of these failures are entirely different. The failures of steel are almost always treacherous; those of iron honest and above board. Leaving out blisters, when an iron plate fails, it fails under the smith's hammer. If it be possible to make a boiler shell of Yorkshire iron, we may rest certain that boiler shell is a good one, and that if it be tested to 150 lbs. it will carry 75 lbs. per square inch with safety. But we have no certainty that if we make an ingot iron shell that shell will be a good one; on the contrary it may crack here, there, and everywhere, and even though it withstands 150 lbs. it by no means follows that it will be quite safe when worked at half that pressure. If the plates come from a given firm the chances are all that the boiler will stand; but if the plates come from another firm, it is quite possible that it will not stand, and this uncertainty exists although every known means of satisfying ourselves that the metal is good, save that of buying the metal in a certain place or from certain firms, has been tried with perfect results.

To assert that these things are not so, or that we draw an exaggerated picture is worse than useless. We happen to know that the history of the failures, which have attended attempts to introduce and to adopt steel as a constructive material, will never be written. It is a sealed book to the general public. We have already explained that those who use steel and find it wanting hold their tongues. Those who make steel are equally desirous to say nothing about their failures. This policy of reticence is to be deplored. Ingot iron is to be the constructive material of the future. In a very few years boilers, ships, everything will be made of it; but a good deal has to be learned first concerning the mode of making it, and the mode of using it to the best advantage. Failures

are as instructive as successes, and more so in this case; and publicity should be courted rather than discouraged. It is no shame to an engineer that a steel boiler has failed; it is no disgrace to the makers of the plates that they have not turned out well; but it is, above and beyond all else in this connection, essential that we should know all about the idiosyncracies of steel or ingot iron. We could easily name many points on which research is required. For example: why is it that local strains may, and undoubtedly do, exist in steel which do not exist in iron? A plate of wrought iron may be found which will bear 25 tons on the square inch tensile strain, and which may be bent and contorted in all sorts of ways, and yet will not break. Holes may be punched in it, and its edges may be sheared without weakening it. An apparently similar steel plate, also with a tensile strength, say, for example, of 25 tons to the inch, and seemingly even more ductile, will crack a few hours after it has been handled, and may be rendered worthless by punching a couple of holes in it, or by shearing the edges. Chemically these plates will be to all appearance nearly identical, why then do the two behave so dissimilarly? It would seem that the answer is to be sought in the method of manufacture. Ingot iron is practically free from cinder, but the very best Lowmoor is not. The molecular arrangement of the steel plate is not fibrous like that of the wrought iron, but either amorphous or crystalline. What part does fiber play? Is it not possible that it distributes strains, carrying them across fixed lines of demarcation? May it not be that fiber acts somewhat as a calico lining to a postal envelope, to use a crude simile, and so toughen more than it strengthens? The great difference between the fracture of a pane of glass—illustrating brittleness—and that of a piece of whalebone—illustrating toughness—is that the line of fracture of the one is definite and precise and in planes, while that of the other is irregular and diffused, and the area of surface separated is, other things being equal, much greater in the one than in the other. Even microscopical fibers may play a very important part indeed in the economy of steel, and much may be learned from an examination of the surfaces of fractured plates, both of wrought iron and ingot iron, which will be of future use. If it can be shown that the best ingot iron for constructive purposes is that which shows most indications of the presence of fiber in its composition, a great deal will have been gained. Chemistry has, too, something yet to learn and to teach us. Amongst other things, why small quantities of sulphur phosphorus and silicon should affect ingot iron far more prejudicially than they affect wrought iron as made in the puddling furnace. It has been said, for example, that the steel of the Livadia's boilers contained 0.09 per cent. of silicon. We have good reason to doubt the accuracy of this statement; but, supposing it to be true, it is quite certain that wrought iron plates containing that amount of the impurity would not have behaved as did the ingot iron of which the Livadia's boilers were made. Why?

PROFESSOR KIRCHOFF ON LIGHTNING RODS.

The city gas company of Berlin, having expressed the fear that gas pipes may be injured by lightning passing down a rod that is connected with the pipes, Professor Kirchhoff has published the following reply: "As the erection of lightning rods is older than the system of gas and water pipes as they now exist in nearly all large cities, we find scarcely anything in early literature in regard to connecting the earth end of lightning rods with these metallic pipes, and in modern times most manufacturers of lightning rods, when putting them up, pay no attention to pipes in or near the building that is to be protected." Kirchhoff is of the opinion, supported by the views of a series of professional authorities, that the frequent recent cases of injury from lightning to buildings that had been protected for years by their rods, are due to a neglect of

these large masses of metal. The Nicolai Church, in Griefswald, has been frequently struck by lightning, but was protected from injury by its rods. In 1876, however, lightning struck the tower and set it on fire. A few weeks before the church had had gas pipes put in it. No one seems to have thought that the new masses of metal which had been brought into the church could have any effect on the course of the lightning, otherwise the lightning rods would have been connected with the gas pipes, or the earth connection been prolonged to proximity with the pipe. A similar circumstance occurred in the Nicolai Church in Stralsund. The lightning destroyed the rod in many places, although it received several strokes in 1856, and conducted them safely to the earth. Here, too, the cause of injury was in the neglect of the gas pipes, which were first laid in the neighborhood of the church in 1859, shortly before the lightning struck it. The injury done to the schoolhouse in Elmshorn, in 1876, and on the St. Lawrence Church, at Itzehoe, in 1877, both buildings being provided with rods, could have been avoided if the rods had been connected with the adjacent gas pipes.

"If it were possible," says Kirchhoff, "to make the earth connection so large that the resistance which the electric current meets with when it leaves the metallic conducting surface of the rod to enter the moist earth, or earth water, would be zero, then it would be unnecessary to connect the rods with the gas and water pipes. We are not able, even at an immense expense, to make the earth connections so large as to compete with the conducting power of metallic gas and water pipes, the total length of which is frequently many miles, and the surface in contact with the moist earth is thousands of square miles. Hence the electric current prefers for its discharge the extensive net of the system of pipes to that of the earth connection of the rods, and this alone is the cause of the lightning leaving its own conductor."

Regarding the fear that gas and water pipes could be injured, the author says:

"I know of no case where lightning was destroyed a gas or water pipe which was connected with the lightning rod, but I do know cases already in which the pipes were destroyed by lightning because they were not connected with it. In May, 1809, lightning struck the rod on Count Von Seefeld's castle, and sprang from it to a small water pipe, which was about 80 meters from the end of the rod, and burst it. Another case happened in Basel, July 9, 1849. In a violent shower one stroke of lightning followed the rod on a house down into the earth, then jumped from it to a city water pipe, a meter distant, made of cast iron. It destroyed several lengths of pipe, which were packed at the joints with pitch and hemp. A third case, which was related to me by Professor Helmholtz, occurred last year in Gratz. Then, too, the lightning left the rod and sprang over to the city gas pipes; even a gas explosion is said to have resulted. In all three cases the rods were not connected with the pipes. If they had been connected the mechanical effect of lightning on the metallic pipes would have been null in the first and third cases, and in the second the damage would have been slight. If the water pipes in Basel had been joined with lead instead of pitch, no mechanical effect could have been produced. The mechanical effect of an electrical discharge is greatest where the electric fluid springs from one body to another. The wider this jump the more powerful is the mechanical effect. The electrical discharge of a thunder cloud upon the point of a lightning rod may melt or bend it, while the rod itself remains uninjured. If the conductor, however, is insufficient to receive and carry off the charge of electricity, it will leap from the conductor to another body. Where the lightning leaves the conductor its mechanical effect is again exerted, so that the rod is torn, melted, or bent. So, too, is that spot of the body on which it leaps. In the examples above given it was a lead pipe in the first place, a gas pipe in the last case, to which the lightning leaped when it left the rod, and which were destroyed. Such injuries to water and gas pipes near lightning rods must certainly be quite frequent. It would be desirable to bring them to light, so as to obtain proof that it is more advantageous, both for the rods and the buildings which they protect, as well as for the gas and

water pipes, to have both intimately connected. Finally, I would mention two cases of lightning striking rods closely united with the gas and water pipes. The first happened in Dusseldorf, July 23rd, 1878, on the new Art Academy; the other August 19th, lastyear, at Steglitz. In both cases the lightning rod, the buildings, and the pipes were uninjured."—*Deutschen Bauzeitung.*

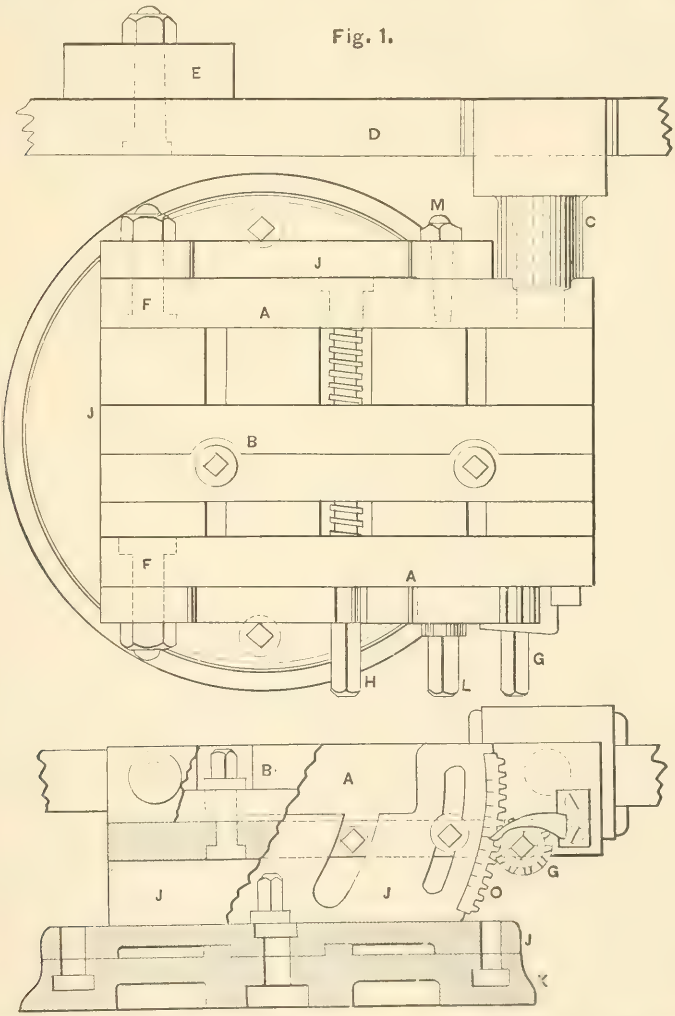
A NEW TOOL FOR MACHINISTS.

By S. W. ROBINSON, Professor of Mechanical Engineering, Ohio State University.

Written for Van Nostrand's Engineering Magazine.

This tool passes as a sort of a planer chuck, but in reality it represents the connecting link between the lathe and planer. Heretofore the machinist has been limited in the means for forming circular surfaces. A wide gap has existed till the present in the system of machinist's tools, by reason of which it has been impossible to directly form iron, &c., to circular surfaces, with radii greater than could be done in the largest lathes. I say system, meaning that the

Fig. 1.



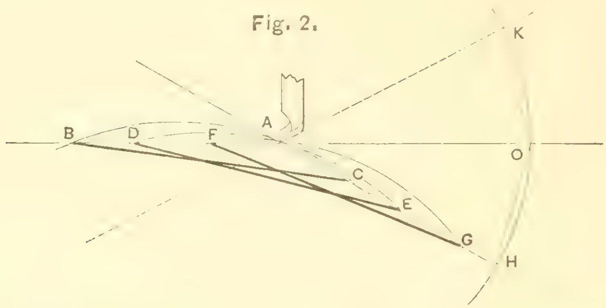
cumbersome bracketed attachment to the planer used for planing links, requiring a nest of accessories for special sizes, with nothing complete and general about it, could hardly be considered as belonging to a system. The device, or chuck, now considered, is complete in itself; always ready for dressing a piece of work to segmental circular form of any radius, and completing the range from two or three feet radius to straight, including concave and convex.

The present intention of the inventor* is to put the invention in the form of a chuck for the planer; but for the sake of the system it may take the form of an entirely new tool, complete in itself from the foundation up. As a planer chuck, in a convenient form, it is well represented in Fig. 1, showing a plan and longitudinal section. It consists of at least three essential parts, viz.: 1st, a bed-piece to set on the planer platen, with two side-pieces or standards; 2d, a vise for holding the work, pivoted by a horizontal axis to the side pieces of the first piece; and 3d, of a guide bar, settable at different inclinations in a vertical plane, and held firmly on the frame of the planer. Along this bar slides a projection from one end of the vise, as the planer is in motion, causing the vise to swing up and down, as a piece of work held in the vise is brought under the action of a tool fixed in the tool-holder of planer, we quite readily see a curve will be cut. Our present object is to investigate this curve on a rigorous mathematical basis. We will state that under one condition it will be theoretically a true circle; and under others, very nearly so, in theory; exactly so, to all intents and purposes, in practice.

* Mr J. H. Greenwood, Columbus, O.

Before taking up the theory, it will be advisable to describe the chuck in one good form, in fact as now made. In Fig. 1, A is the vise for holding the work. It consists essentially of a bottom and side pieces. Between the latter slides a jaw B, forced by the screw H, for securing the work to be dressed. Set screws pass through the jaw, which can be finally set against the work for greater security. The screw H draws instead of pushes, so as to avoid springing the vise bed. At one end of the vise are the pivots F, about which the vise swings. These pivots are fixed in the side pieces J, of the next piece below B, and constitute the horizontal axis about which the vise swings, as stated. The side pieces J are solid on one bed piece, also marked J, all carried so as to swing around horizontally on a base plate K, which latter is secured to the platen by bolts and dowels. The edge between J and K is graduated, so that any angle can be set off. When the vise is set level, and fixed in J, by the taper pin M, we have an index chuck. Hence it is never necessary to remove this chuck to put on a common one. At C is the cross-head socket projecting from one end of the vise. The cross head is gibbed upon D, and swiveled in C. At E is a bracket bolted to the body of the planer below the platen. It serves to fix the guide-bar pivot E. At the other end of D is a slotted arc for making fast that end. This arc is bolted to the uprights of the planer, and by it this end of D can be set to any inclination up or down.

Fig. 2.



In attaching the chuck to the planer, two points should be carefully observed. 1st. The guide pivot E should be placed exactly at the height of the chuck pivots F. 2d. The same point E should be no farther forward or back than exactly op-

posite the point of the average tool, held ready for work in the tool-holder of the planer.

These points observed, we readily see that Fig. 2 is a correct diagrammatic exhibit of those parts of the chuck which constitute the new features. Thus, BAO is the path traversed by the "chuck pivot," while AGH is the guide bar, and A the "guide pivot." Also, A is one tool position. The vise is represented in three successive positions, viz., BC, DE, and FG, BDF being positions of the chuck-pivot, and CEG the corresponding ones of the cross head. This diagram answers to the supposition that the observer stands upon the floor alongside the planer. But suppose the observer to station himself upon the vise of the chuck while in operation. Then the vise appears stationary, while the tool and guide pivot A, the chuck-pivot path BAO, and the guide bar AH, appear to move.

Fig. 3.

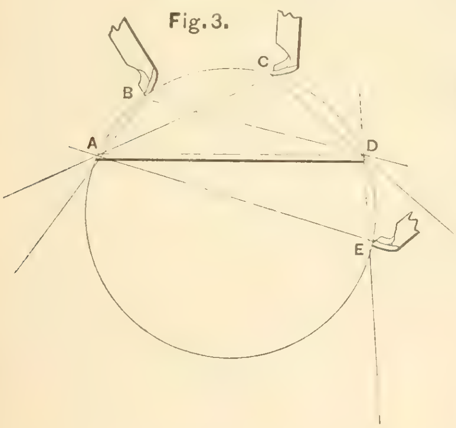
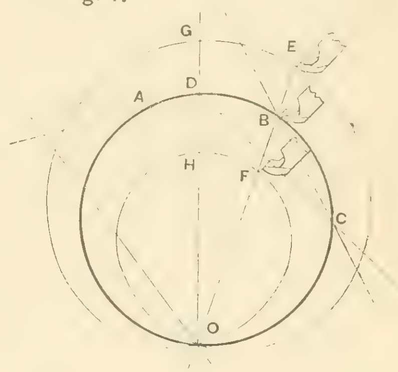


Fig. 3 is at once seen to answer to this supposition, where AD is the stationary vise, and B, C, E, &c., positions of the tool and guide pivot. The chuck-pivot path and guide bar will appear to occupy the positions ABD, ACD, AED, &c., corresponding to the tool position named.

This diagram brings us directly to the geometry of the chuck. From the nature of the case, we know that while the chuck is in operation, planing any given piece of work, the angles ABD, ACD, &c., are all equal. From geometry, we know that the curve passing through A, B, C, D, E, &c., is a circle, because the constant angle ABD, ACD, &c., is measured by half the circular arc AED. Hence, when the tool is at the guide-bar pivot, the chuck "planes" a circle arc exactly in theory. In practice this circle arc sweeps through space while being planed, as Fig. 2 shows, and there is probably doubt as to the circular form of the tool cut line, where the tool is raised or lowered, or forward or back of the guide pivot.

Fig. 4.



By the help of Fig. 4, we gain an insight to the nature of the curves when the tool is displaced. This figure is an extension of Fig. 3. Let ABCO stand for the circle of Fig. 3, cut when the tool is at the guide center, and EG the curve cut when the tool is raised to E. Draw the straight line EBO through E and B. It makes a certain angle with the chuck pivot path AB, and with the guide-bar BC. These lines move to AD and DC when B moves to D. A line GDO will make the same angle with AD as EBO does with AB, because the angles ADO and ABO are measured by half the arc AO. Hence, if DG=BE the tool E will be at G, when B moves to D, because in practice the tool, in making a cut, remains stationary relatively to the guide bar, &c.

From these considerations we find a simple means for constructing the curve EG on a drawing board. We only have to draw a circle ABO, Fig. 4; then through O draw any desired number of straight lines, distributed about, and then, with a constant span in the dividers, lay off BE, DG, &c., on all the lines. Then trace the curve through the points EG, &c., thus found. The curve runs into the point O from both sides, and is sometimes classified as a

conchoid with a circular base; sometimes as the limaçon of Pascal. (See VAN NOSTRAND'S SCIENCE SERIES No. 47, by J. D. De Roos, reprinted from this MAGAZINE.) If the tool be lowered to F, we have the same curve, but inside the base circle, and constructed by laying off BF on all the lines, when BF=BE the two curves are one and the same, continuous through O.

This curve is evidently one of varying curvature, and hence not circular at any part. It remains to be shown whether the curve will deviate from a circle appreciably within the limits reached in practical use of the chuck. This can only be determined by aid of qualitative results, computed from rigorously correct formulas. Drawings cannot be made accurate enough for the present purpose.

Let R=radius of the circle ACO, Fig. 4.
- r=radius-vector of the conchoid pole of co-ordinates at O.
- ρ=radius of curvature of the conchoid.
- θ=angle to r.
- α=angle to ρ.
- a=elevation of tool, minus for lowered.
- x=deviation of curve from circle.

Also $r=r_0$ & $\rho=\rho_0$ for θ & $\alpha=o$.

Then the polar equation of the curve, pole at O, and θ reckoned from at diameter through O, is

$$r=2R\cos\theta+a \quad . \quad . \quad . \quad (1)$$

which is evident from the fact that $2R\cos\theta$ is that part of r, between O and the circle, as OD, and a is the part DG, when the curve is inside the circle, a is minus, and

$$r'=2R\cos\theta-a \quad . \quad . \quad . \quad (2)$$

To find the radius of curvature for any point G, we may apply the differential formula of the calculus. Substituting into it the differential coefficients obtained from (1) we have

$$\rho=\frac{(r^2+4R^2\sin^2\theta)^{\frac{3}{2}}}{r^2+8R^2\sin^2\theta+2Rr\cos\theta}$$

$$=r\frac{\left(1+\frac{4R^2}{r^2}\sin^2\theta\right)^{\frac{3}{2}}}{1+\frac{8R^2}{r^2}\sin^2\theta+\frac{2R}{r}\cos\theta} \quad . \quad . \quad . \quad (3)$$

for which r is given by (1).

If r' from (2) is used, the radius of curvature obtained is for the inside curve.

When $\theta=0$, we obtain

$$\rho_0=\frac{r_0^2}{r_0+2R}=\frac{(2R+a)^2}{4R+a}$$

$$=R+\tfrac{3}{4}a+\frac{a^2}{4(4R+a)} \quad . \quad . \quad . \quad (4)$$

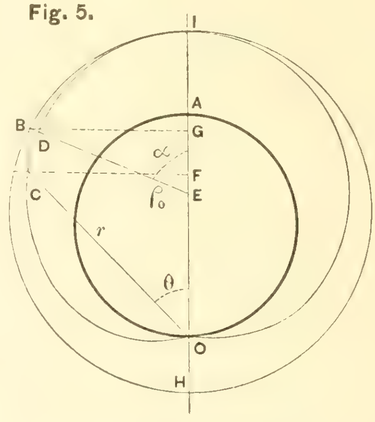
$$\rho_0-R=\tfrac{3}{4}a+\frac{a^2}{16R}=\tfrac{3}{4}a\text{, nearly} \quad . \quad . \quad . \quad (5)$$

The 3d expression of (4) comes from algebraic division after developing the numerator of the 2d. Eq. (5) comes from the last of (4) by dropping a from the denominator and transposing R. This eq. (5) is important, because it shows the change in the radius of the work cut when the tool is raised or lowered, with respect to the guide pivot.

Solving (4) for r_0, observing that $2R=r_0-a$, we obtain

$$r_0=\rho_0\left(1+\sqrt{1+\frac{a}{\rho_0}}\right) \quad . \quad . \quad . \quad . \quad (6)$$

Fig. 5.



In Fig 5, let GO represent the base circle, ICO the conchoid, and IBH the circle of radius ρ_0, which osculates with the conchoid at I. Then BD is the perpendicular, or normal departure of the conchoid from the osculatory circle, and shows how much the curve, planed in the chuck, departs at B, from the circle it begins to cut in starting at I, when the tool is raised to the height AI. The magnitude of this is of the utmost importance, for upon it the utility of the invention in a great measure depends; that is, if it is found to be always too insignificant to perceive in practice, the

non-circular character of the curve cut can be ignored, and the chuck used as though theoretically perfect. The value of $BD=x=BC\cos\alpha$, and $BC=GF=GE+EO-FO=\rho_0\cos\alpha+r_0-\rho_0-r\cos\theta$. Hence

$$x=(\rho_0\cos\alpha+r_0-\rho_0-r\cos\theta)\cos\alpha$$
$$=\rho_0\left\{\cos\alpha+\left(\frac{r_0}{\rho_0}-1\right)-\frac{r}{\rho_0}\cos\theta\right\}\cos\alpha \quad . \quad . \quad . \quad . \quad (7)$$

The relation of θ and α is

$$\rho_0\sin\alpha=r\sin\theta.$$

We readily see from Fig. 5 that when the tool is raised up along the continuation of the diametrical line OA to I; the work should be so disposed in the chuck as to be dressed to include equal portions of the curve like IB on each side of I. This very nearly follows in practice as a matter of course, but not exactly since the tool will move in a line EBF, perpendicular to the chuck-pivot path AB Fig. 4. But as the angle ABC is in practice 180° within 15° or less, there is but little chance for error here. Also it is plain that when AI, Fig. 5, is large, x is greater. Again if the radius EI is small for a given length of work, x is greater.

We will take an example, which thus represents an extreme case, in which the radius is $R=30$ inches, the length of work 24 inches, and the elevation, or depression of tool, $a=4$ inches. The necessary computations give for

TOOL ELEVATED.

$$r_0=2R+a=64''$$
$$r=62''.8978.$$
$$\theta=11°$$
$$\rho_0=33''.0323$$
$$\rho=32''.9806$$
$$\rho_0-\rho=+''.0517$$
$$x=\ ''.000614$$

TOOL DEPRESSED.

$$r_0'=2R-a=56''$$
$$r'=54''.4622$$
$$\theta'=13°$$
$$\rho_0'=27''.0345$$
$$\rho'=27''.1168$$
$$\rho_0'-\rho'=-''.0823$$
$$x'=-''.00219$$

The values of r, r', ρ, and ρ' are for the ends of the piece 2 ft. long, supposed, in the example, to be planed off. The intercepts x and x' are also at the ends of the work. In practice we probably never would have occasion to work to a shorter radius, or to a greater length of piece for that radius, and never with a greater elevation of tool; in short, never would give cause for greater theoretical departures from the strictly circular form, and yet we find it to be less than a thousandth of an inch for the outside curve, and only about two thousandths for the inside one. These are undiscoverable by means in the hands of machinists, applied to pieces of the size considered, and hence of no practical consequence. Considering again that the departure is from a circle fitting the middle of the work, and not from that one going through the three points consisting of the midddle and end points; we find that the departure computed appears in its exaggerated form. When a three-point templet is used in connection with the chuck for fitting up the work, the triple contact comparison circle will be the one realized. Then the departures will be only about a fourth as large as the computed ones, as can be shown from an approximate law of curves not necessary to discuss here. They can, in fact, be seen to be much smaller.

When we thus find that the theoretical departures of the work produced by the chuck, from the desired circular form, can never exceed two thousandths of an inch at the worst, and generally will not exceed about half a thousandth, of course there need be no hesitation, on theoretical grounds, about adopting the chuck. And, finally, when we consider that the practical errors due to elastic yielding of materials, imperfections in sight, measurements, &c., will swallow up all the theoretical ones without knowing the difference; that is, when the theoretical errors of the chuck utterly vanish within practical ones foreign to it, but incident to its use, we may safely assume that for all practical intents and purposes this chuck is a theoretically perfect tool, and may be offered as such.

In using the chuck for fitting work, two methods are available for securing a given radius to the circle planed. 1st a three-point templet, or, if preferred, a circular templet may be employed. And, 2nd, a table of setting values for the

guide bar. These may be used separately or conjointly; probably the latter will always be found preferable.

The templet method supposes a templet of some form. It may be a circular segment, cut from sheet metal. Where much work is repeated to the same radius, such a one will be more durable than that of three points, though the latter can be produced most readily. An adjustable templet or gauge will be found convenient, in which one of the three points, or legs, can be set by a scale and vernier, according to a table prepared for it.

The table method of setting the chuck requires a table of values of radii of work, and of the angular elevation or depression of the guide bar. In Fig. 2, the position AH of the guide bar may be determined by the chord OH, called the "setting," the same being set off by a steel rule. Similarly OK is the chord for the opposite setting.

To compute values of these chords, take the setting OH, or OK equal y. Take $AO=AH=d$. Also take the angle $OAH=\varphi$; and the length of the vise, from pivot to cross head, $=l=BC$ or FG, Fig. 2. Then

$$Ok \text{ or } OH=y=2d\sin\tfrac{1}{2}\varphi \quad . \quad . \quad . \quad (8)$$

Also in Fig. 3, supposing E to be diametrically opposite A, observing that $AED=\varphi$, we would have

$$AE\sin\varphi=AD=2R\sin\varphi=l \quad . \quad . \quad . \quad (9)$$

From these equations, y can be computed for assumed values of d and l; φ being regarded as an auxiliary quantity. By eliminating φ, we obtain

$$\frac{R}{l}\left(\frac{4d^2}{y^2}-1\right)^{\frac{1}{2}}=\frac{d^2}{y^2} \quad . \quad . \quad . \quad (10)$$

which shows that R varies directly as l, and y directly as d. This must be observed in changing a table for any one chuck to fit another. In addition to these "settings," the table should contain "setting corrections" to use in compensating the radius of the work for elevation or depression of tool. That is to say, when the chuck is set for a given radius of 60 inches, for instance; then if the tool should be raised 2 inches, by which a change of $1\frac{1}{2}$ inches in the radius is occasioned (see eq. (5)), we should have a value of the change of setting required to restore the 60 inch radius. This is the "setting correction."

The relation sought in this, is that between differences of the radius and differences of the settings, or between $d\rho_0$ and dy. This relation can be found from eqs. (5), (8), and (9), observing the conditions that when the tool is fixed at a certain point in height, we change the setting to effect a change in ρ_0. In doing this we vary φ, and R. Hence the 1st of (5) gives

$$\frac{d\rho_0}{dy}=\left(1-\frac{a^2}{16R^2}\right)\frac{dR}{dy} \quad . \quad . \quad . \quad (11)$$

By aid of (8), and $\sin\varphi=2\sin\frac{1}{2}\varphi\cos\frac{1}{2}\varphi$, (9) may be transformed to $2Ry\cos\frac{1}{2}\varphi=ld$, whence

$$\frac{dR}{dy}=\frac{R\sin\frac{1}{2}\varphi}{2\cos\frac{1}{2}\varphi}\frac{d\varphi}{dy}-\frac{R}{y} \quad . \quad . \quad . \quad (12)$$

And (8) gives

$$\frac{d\varphi}{dy}=\frac{1}{d\cos\frac{1}{2}\varphi} \quad . \quad . \quad . \quad (13)$$

Combining eqs. (11), (12), (13), & (8), with (9) transformed, we obtain

$$\frac{d\rho_0}{dy}=-\frac{R}{y}\left(1-\frac{a^2}{16R^2}\right)\left(1-\frac{R^2y^4}{l^2d^4}\right) \quad . \quad . \quad (14)$$

By dropping the last term in each of the bracketed expressions, we introduce an error which only reaches a hundredth of an inch for one or two of the greatest corrections, in others it being less. Hence the simple relation

$$\frac{d\rho_0}{dy}=-\frac{R}{y}\text{ nearly} \quad . \quad . \quad . \quad (15)$$

These formulas give but little idea of the table, and much depends upon them in the line of practical convenience. A specimen of the tables is given to enable the reader to judge of their applicability.

TABLE FOR SETTING THE CHUCK.

Radius of curve planed. Tool point at "guide-pivot."	"Setting" of guide-bar, 2 ft. from "guide-pivot."	"Setting correction" for tool, 1 in. up or down, to plane a given arc.
Inches.	Inches.	Inches.
195.03	1	.004
156.02	1.25	.006
130.07	1.5	.009
97.58	2	.015
78.11	2.5	.024
65.13	3	.034
55.86	3.5	.047
48.92	4	.062
43.53	4.5	.077
39.21	5	.095
35.69	5.5	.115
32.77	6	.135

TABLE OF INSTRUCTIONS.

Curvature planed.	Tool raised or lowered.	Radius of planing.	Setting, up or down.	Correction of setting.
Convex.	Raised.	Increased	D'nward	Add.
"	Lowered	Decreased	"	Subtract
Concave	Raised.	Decreased	Upward	Subtract
"	Lowered	Increased	"	Add.

NOTE.—"Guide pivot" is the pivot of guide bar, and the chuck pivot should be at the same height.

Each inch the tool is raised or lowered makes $\frac{3}{4}$ inch change in the radius planed, except the setting is corrected as in last column of table.

What is here termed the "setting" is the length of the chord OH or OK. Fig. 2. When AO = AH = AK = 24 inches, and the length of the vise from chuck pivot to axis of cross head is $16\frac{1}{4}$ inches.

The "setting correction" is to be applied to the "setting," for the purpose of restoring the given radius planed, after the tool has been raised or lowered.

When the tool is back of the guide pivot, that end of the work, which is in the opposite direction, has slightly the sharpest curvature, and *vice versa.*

As regards the seeming multiplicity of the means for setting the chuck to its work, and the possible objection to it which may be imagined on this ground, it is but fair to mention the fact that the table may be regarded and treated as a convenience instead of necessity. Setting the table aside, and adopting the three-legged templet, we are on an equal footing with the lathe and its calipers for working to given dimensions. In the lathe we think nothing of setting the calipers by a scale, rounding the piece of work and trying on the calipers. If not a fit, we cut and try again—and again—till correct. Exactly so with the chuck and its templet. But the chuck is more complete than the time-honored lathe, in that it has a means of coming directly to the mark, while the lathe has not.

The great indebtedness of iron manufacturers to Mr. Greenwood, for this valuble invention, can only be duly appreciated by observing the important gap which it fills in the system of machine tools, and the readiness with which surfaces may now be produced, which could not heretofore be employed to any extent, from the impossibility of producing them plentifully.

HELIOGRAPHY AND SIGNALING.

By MAJOR A. S. WYNNE.

From the "Journal of the Royal United Service Institution."

IT is now nearly five years since a lecture on the heliograph or sun-telegraph was delivered by Mr. Samuel Goode, who claimed for Mr. H. C. Mance, of the Government Persian Gulf Telegraph Department, the invention of this valuable instrument for signaling purposes. It was then explained that as early as the year 1869, Mr. Mance brought his heliograph to the notice of the Government of India. It was very favorably received, and subsequent reports testified to the success of experiments which had been tried to ranges of 50 miles without telescopes, one memorandum going so far as to state that with a 6 or 8 inch mirror, signals could be seen with the naked eye at a distance of 100 miles.

Since then the heliograph has fully realized the expectations of its supporters. The Government of India sanctioned its adoption in 1875, and each succeeding year its efficiency has been more and more generally recognized. It was used for the first time on active service, in India during the Jowaki-Affridi Expedition of 1877–78, and in the campaigns of the last two years in Afghanistan and Zululand it has has been put to every possible test, with such satisfactory results that it must soon become an established addition to the Signaling Equipment of all armies.

It is not my purpose to advance the many instances in which sun-flashing has been employed advantageously elsewhere

than on the northwestern frontier of India. Most of us have read with what good effect it was eventually used at Ekowe and in the subsequent operations against Cetewayo and Seccocoeni; of its having been brought into play by the Spaniards across the Straits of Gibraltar; and by our own people in Australia and the West Indian Islands. We know that it forms part of the signaling equipment of the United States Forces, and as I am informed of other armies, all of whom will have points of interest to record.

My experience of the heliograph has been mainly acquired in a practical way on service. I have nothing to add to the theoretical knowledge of sun telegraphy; but as I had the honor and good fortune to be placed in superintendence of the signaling operations with the Peshawur Column of the Jowaki Expedition and of the Kuram Column during the first phase of the Afghan Campaign, I shall endeavor to explain as far as possible the results obtained and the inferences to be drawn from the working of the heliograph during those campaigns; and if any hint or suggestion I can give should prove of assistance to such of my brother officers as may at any time be similarly placed, I shall not regret that my diffidence in appearing here has been overcome.

Origin of the Heliograph.—Reviewing rapidly the origin of the heliograph, the system of utilizing sunlight as a means of communication seems to have been known to the ancient Greeks and Romans. In the earlier part of this century a sun-flashing instrument called the heliostat was used in survey operations; and by its means triangles with sides exceeding 100 miles each were laid down in the Survey of the British Isles. The heliotrope, an improvement on the heliostat, has long been and is still very generally used; though somewhat cumbersome, its construction is simple, and it is provided with the means of horizontal and vertical adjustments. Then came the heliograph, which, like most inventions when once introduced and established, seems so simple, that the wonder is the other instruments did not sooner suggest the idea of utilizing the sun as a signaling agent, by converting rays of light into active speaking signs, and adapting the flashes to a code.

While there will be something to learn from every new experience of the use of sun-flashing, it may be well to guard against many doubtful reports that are current of its application. Thus, while it is, no doubt, true that some primitive method of sun-flashing has long been employed by the North American Indians for war purposes, I have seen it stated that when some years ago, in the plains west of the Missouri River, 3,000 warriors of the Dakota tribe encountered an invading column of the United States Army, they not only adopted regular formations for attack and defence, but were maneuvered by means of a looking-glass which their chief held in his hand. The strong ray of reflected sunlight it is said was thrown on the ground, and moved in whichever direction the chief wished his force to take, they following the flash as it moved along the ground. At first sight this seems plausible enough, but to any one conversant with sun-signaling, the impracticability of the alleged method is at once apparent, for the flash from even a very large mirror, if projected on to the ground, becomes invisible at 100 or 200 yards distance, both to the signaler and those signaled to. Again, it is said that the Russians made use of sun-flashing for signaling purposes during the siege of Sebastopol; the following extract from a letter of the *Times* Correspondent having appeared on 11th July, 1855:

"A long train of provisions came into Sebastopol to-day, and the Mirror Telegraph, which works by flashes from a mound over the Belbeck, was exceedingly busy all the forenoon;" it is singular, however, if such were the case, that they should have so forgotten the art as not to have employed it during the late war with the Turks, when on many occasions it would have been of such value. For instance, in Asia Minor a pre-arranged joint attack was to have been made on the Turkish position, a few miles east of Erzeroom, by two columns marching along converging routes; one column was, however, delayed, and a separate instead of a combined attack resulted in the defeat of the Russian forces in detail, who were driven thence back to Kars. Had intercommunication been maintained by sun-flashing (and I have no doubt it was feasible) the march might have

been so timed as to insure a simultaneous assault. If the Russians had possessed a sun-flashing instrument, one might have expected to see it employed as a means of communication across the Danube and round Plevna, but so far as I can gather, heliographic signaling was not resorted to throughout the campaign. It is not improbable—but I throw it out merely as a suggestion—that the flashes came from some reflecting surface accidentally placed in line with the English camp. I have often seen effects not easily distinguishable at first from heliographic signals. For instance, during the three days General Roberts' force was encamped below the Afghan position at the head of the Kuram Valley, attention was attracted each morning at sunrise by flashes from the enemy's camp, and it was thought at first that they had a heliograph; but a careful scrutiny through a glass showed the light to be from the muzzle of a polished brass field gun. We may be sure that if the Russians had employed a signaling mirror they would not have exposed the signals to our observation, also that the fact would have been prominently mentioned in their official reports of the siege.

The introduction of the heliograph cannot fail to have a stimulating effect on army signaling generally. Various methods of conveying intelligence to a distance by signals have been in vogue during the last few years in both the army and navy. So long ago as 1851, an "occulting telegraph" was invented by the late Charles Babbage, in which it is said the Duke of Wellington took much interest, and when the report came home during the Crimean war that the Russians were using a mirror telegraph which worked by flashes, the inventor addressed a letter to the *Times*, and suggested the idea of adapting sunlight to his system. Nothing seems, however, to have come of it, and until quite lately the army has been contented, or rather discontented, with such apparatus as flags, semaphores, shutters, lamps, &c., &c. For, notwithstanding all the methods of communication which have from time to time been adopted (and the system and apparatus of Captain Colomb and Colonel Bolton are very admirable), and however useful they may have proved in their different spheres, it is undoubtedly a fact that army signaling has languished, chiefly owing to the limited powers of the apparatus employed. Even the best of all signaling means, the field telegraph, is not without its defects, some of which I shall have occasion to allude to later on. Like everything else, sun signaling has serious shortcomings, still the heliograph has proved both in India and Africa a valuable addition to Army Signaling Equipment. Amongst the many advantages that may be fairly claimed for it are its great range, portability, the ease with which it can be established and communication maintained, and the rapidity of its working. If the ranges at which the operations during recent campaigns were conducted seem somewhat short, it must be remembered that the stations were established to suit the positions of the troops, and that experiments to test the limit of the range were not attempted. For instance, we read of twenty-four heliograph stations having been employed between Cabul and Jumrood, but it must not be inferred from this that when through communication is required, so many points are necessary, for the whole distance of 180 miles from Cabul to Peshawur can, without difficulty, be accomplished through four intermediate stations, signaling between Cabul and the heights above Jellalabad, distant 75 miles, having been successfully carried on through a single station at Luttabund. It may be stated that under favorable conditions of sun and atmosphere, any two points visible to each other can be brought into communication.

Description of the Heliograph.—Several patterns and sizes of heliographs exist, in some of which there are departures from the original Mance instrument. The heliographs here, one of which is from Roorkee, have been kindly lent by Mr. Goode. I am sorry I have none of those made more recently in India, for the regiments out there are exclusively equipped with instruments made in the Government workshops there, on the Mance principle. The Superintendent of the Canal Foundry has taken especial interest in their manufacture and been ready at all times to carry out suggestions for improvements

in constructive details. However, without entering into slight differences of construction, I will describe the instrument now before you. It consists of a signaling mirror, reflector, sighting vane, and two tripod stands. The signaling mirror is so connected to the framework of the instrument that its inclination can be regulated horizontally or vertically. A tangent screw engaging the base plate enables the frame to be rotated, and a telescopic rod clamped to the signaling key lever, and working by screw through a nut at the top of the mirror, effects the vertical adjustment. There is a small circular hole in the frame of the mirror, and a corresponding unsilvered spot in the mirror itself, to enable an alignment with the distant station being taken when looking through from the back of the instrument.

The reflector is used when the sun is behind the operator, and should replace the sighting vane whenever the angle made by the sun, the heliograph, and the distant station exceeds 120°. The reflector has a sighting vane attached to its surface.

The sighting rod is so jointed that it can be readily moved into any position, it fits on to one of the stands, and has a silvered sighting plate, with a black spot in the center called the sighting spot.

One tripod stand supports the signaling mirror and the other the reflector or sighting vane as required.

Sighting with Sun in front of Signaler.—The usual method of directing the flash to the required point has been to look through the mirror from the back and move the sighting plate until the sighting point is exactly in line. But a simpler and very accurate way is to "stand in front of the mirror and looking into it, bring the eye into such a position that the spot in the center of the mirror hides the reflection of the distant station. Then move the sighting rod until the reflection of the sighting spot comes into an exact line with the other two objects." The flash is then thrown on to the sighting vane and is rightly aligned when the dark shadow spot in its center coincides with the spot on the vane. The shadow spot is occasioned by the center of the mirror being unsilvered.

When the heliograph is adjusted, there is no chance of the alignment being disturbed, for however much the inclination of the mirror may be altered, its center, being the axis on which it turns, remains stationary.

Sighting with the Sun behind the Signaler.—When it is necessary to use both mirrors, place the signaling mirror facing the sun and the reflector inclining towards the distant station, stand in front of the heliograph and looking into the mirror so that the whole of the reflector can be seen reflected, move the latter horizontally or vertically, until the distant station, the spot on the reflector, and the unsilvered spot on the signaling mirror are in the same line.

Signaling.—The Morse code is so universally known it may be hardly necessary to remark that it consists of an arrangement of dashes and dots, or longs and shorts, to represent the letters of the alphabet, one of the former being equivalent in duration to three of the latter. The short flash from the heliograph is almost instantaneous, while the long is visible for an appreciable time. By an arrangement of these signs no letter involves more than four signs, whether dots or dashes.

According to the Army Signaling Regulations, no abbreviations are permitted; but I think this is a mistake, and cannot see why those authorized in telegraphy should not be adopted, or at all events those most commonly used.

The "General Answer," which consists of a succession of longs and shorts, kept up until the next word or group is commenced, should be abolished for the heliograph. The instruments receive more rough usage from it than from all the messages despatched. One flash kept up till the commencement of the next word is the best answer, signifying that the word or group is understood, and two short flashes for "not understood" signifying that the word is to be repeated. In the Regulations there is no sign laid down for "not understood," they provide that the word should be repeated if after a reasonable time elapses no answer is sent. And though theoretically this interval is limited to a pause equal to two longs, yet in practice a much greater lapse takes place, the sender hoping that the receiving station

may be induced to take the word on reading the pretext of the message. This causes a serious loss of time which would be obviated by a "not understood" signal. It is these unnecessarily long intervals between words which take up so much valuable time.

When the signaling key lever is depressed, it alters the inclination of the mirror according to the play allowed by an adjusting screw, and if the flash was before truly aligned on the distant observer, it would then be thrown over his head, and become invisible to him, but the pressure being removed the flash would return to its original position and reappear.

Heliographic signaling can be carried on by flashes or the obscuration of a fixed light. In the former case, *when the key is depressed* the center of the flash is directed on to the sighting vane and is then seen by the distant station; when the pressure on the key is released the flash falls and disappears from view. In the latter case the center of the flash is thrown on to the sighting spot and appears as a fixed light to the distant station until the key is depressed, when the flash is thrown upwards. In both instances the method of signaling is the same; long and short flashes, or long and short obscurations resulting from the periods of pressure applied to the signaling key, and in this way the letters of the alphabet according to the Morse code and other useful combinations can be signaled.

Flashing is the system in vogue in the army in India, and is more generally adopted than that of obscuration.

In signaling the left hand is kept on the tangent screw and the right on the signaling key. The necessary adjustments to suit the (apparent) motion of the sun can thus be simultaneously made, while in the act of signaling, without any interruption or delay.

Advantages and Capabilities of the Heliograph.—It has been generally admitted throughout the Afghan campaign, that without heliographs no satisfactory communication could have been maintained. Until the operations developed and arrangements were made with the tribes, no dependence could be placed on the lines of field telegraph, the working of which was constantly rendered inoperative by malicious cutting. Taking the Khyber line for example: up to October, 1879, on a total distance of 108 miles of line, it was cut 98 times and 60 miles of working wire was carried away and never recovered. Considerably more damage has been since committed, and the recent operations at Cabul prove that when most needed the telegraph is almost sure to be cut. In December last, during the investment of Sherpur, the greater part of the line between Cabul and Gundamuck was entirely destroyed. But here the heliograph did good service, enabling the Sherpur garrison to hold communication with the solitary outpost at Luttabund, the connecting link with their supports, along the Khyber route, by which means General Roberts was able to assure the army in India, and the Government at home, of his security, and to issue important orders regarding reinforcements.

The service the heliograph has rendered in other ways during the campaign has been scarcely of less value, and the long lines of communication which by its use have been kept open have not only assisted the operations in the field, but spared cavalry and infantry much harassing duty in conveying messages from post to post.

Flags were quite useless as a rule to work over the distances which separated brigades and detachments; henceforth they will probably be confined to sunless days, for when the distance exceeds 4 or 5 miles a flag of such size must be used that working it for any length of time entails much physical labor and is tediously slow. Small flags for shorter distances may, in many cases, be of great service, but generally speaking as the distance diminishes it will be found quite as convenient, if not as expeditious, to despatch messages by mounted men or even foot messengers if the heliograph cannot be worked.

Amongst the many merits of the heliograph, the ease and certainty of attracting attention must not be overlooked. Every inch of country visible can be gradually searched by its means, and the positions of parties unknown before ascertained. If the tangent screw is pressed outwards, the mirror will turn freely right or left, and by loosening the screw which clamps the key-rod in

its socket, the inclination of the mirror can be raised or lowered at pleasure.

The capture of the Peiwar Kotal on the 2nd December, 1878, was effected by two columns, one of which attacked in front, the other in flank. The configuration of the country did not admit of direct heliographic communication between them, but it was practicable by the establishment of an intermediate station. The detached signaling party, however, failed to reach the pre-arranged point, but by flashing all over the hill-side in the way I have indicated, their actual position was discovered, and interchange of messages effected.

During a surveying expedition made in January, 1879, from Khost into the Waziri Hills under Captain (now Major) Woodthorpe, R.E., I accompanied the party, and from one of the first hills where the surveying plane table was set up, Banu, a station 35 miles distant, and within the frontier of India, could just be seen lying at the foot of the hills on the banks of the Kuram River, and apparently not far from the Indus. A heliograph was directed on Banu, and although no previous intimation had been given, and there was only one officer present at the station who possessed a heliograph, communication was soon opened; signaling had all along been maintained with the Head-Quarters at Khost, and messages were now passed between General Roberts and the officer commanding the frontier. Banu being also in connection with the telegraph system of India, a message from the General was dispatched to the Viceroy at Calcutta. It was afterwards found that a native sentry had noticed the flash from the hills and given intimation. From the same point, communication with Hasar Pir (distant 19 miles) was established, the attention of the signalers having been easily attracted.

From the Kandahar Field Force, it is reported that on the 12th December, 1878, a camp being discovered lying under the Kojak Range, distant 20 miles, a heliograph was laid on it, and a reply soon received. After marching 8 miles further on the same day, communication was opened with a camp 25 miles off, which turned out to be the head-quarters of General Biddulph's division.

Again, on the 29th May, Captain Straton, Superintendent of Army Signaling with the Kuram Field Force, ascended the Sufed Koh—a range of mountains 15,000 feet above sea level, and separating the Kuram and Cabul valleys. Intimation had been sent to Jellalabad, warning the signalers to be on the alert, but when Captain Straton reached the top of the Agam Pass, he found Jellalabad obscured in a dust storm which continued throughout the day: however, he proceeded to the Karaini Peak, close by, and carefully scanning the Cabul Valley through a telescope, discovered a camp which proved to be Gundamuck, distant about 30 miles. With Mance's 3-inch heliograph he attracted attention, and in fifteen minutes Generals Roberts and Browne, Commanding the Peshawur and Kuram Columns, were in communication.

More recently, with the Zaimusht Expedition under General Tytler, the force was divided into three columns which separated at Mundatoo under Colonels Gordon, Rogers, and Low. The "Pioneer" correspondent accompanying the force writes: "The utility of having this knowledge was well illustrated as we returned from Gondaleh. . . . We caught sight of distant high peaks overhanging the camp at Mundatoo. Over these hills Colonels Gordon and Rogers had taken their troops the day before. Suddenly from about half-way down one of them flash, flash, flash come on to us. . . . Colonel Low called his signalers up, the message was from Colonel Gordon to General Tytler informing him that both would reach the head-quarter camp that night. Thus General Tytler knew the position and whereabouts of all the troops out."

But perhaps one of the most prominent services rendered as yet by the heliograph was during Captain Straton's visit to Jellalabad in January last. On the 12th of that month, when at the signal station of Alibogham, he found out that the Momunds had crossed the Cabul River; this intelligence he at once flashed off to Jellalabad, and that night a brigade started to intercept the enemy. During the following day, communication was successfully maintained between General Bright's head-quarters at Jellalabad, the brigade set out, and a detachment of it, crowning the heights.

At 1.15 P.M. (13th), Captain Straton saw about 1,500 men trying to cross the river, at such a point that, if they had succeeded, the brigade would have been cut of from Jellalabad, and the detachment severed from its main body. But intimation was at once signaled to all concerned, and by 3 P.M. a couple of guns sent out from Jellalabad were shelling the enemy with such good effect that they beat a hasty retreat.

I might quote many other instances of the kind, but those already given suffice to prove that with the heliograph no pre-arrangement as to time or place is, even up to such distances as 35 miles, absolutely necessary.

Signaling by moonlight with the heliograph has been practiced during the last two years on service, and it is hoped that the results will soon be published. I have tried it on two different occasions; first in the Jowaki campaign between General Ross's standing camp and the Sargasha Ridge, and subsequently between Jutogh and Subathu, distant 12 miles. The signals were intelligible in each instance, but the heliographs and telescopes were set up by day and remained in position till the moon rose, otherwise it is doubtful whether the alignment could have been hit off, unless signal fires had been used. At the time communication was established between the Cabul and Kuram Valleys, advantage was taken of a full moon, and a heliograph set on Kuram from the Agam Pass. The light was seen with the naked eye 12 miles off. Selinagraphing might often be very profitably employed; clear nights are the rule in India, and signaling by the reflection of a planet has been carried out for short distances.

Heliographs can also be used with artificial lights; during the investment of Sherpur, they were worked at night with the reflected light from lamps between the different faces of the works, and to the picquets on the adjacent heights where no telegraph existed. It may at first sight appear strange that a reflected light should be used instead of the direct light itself, but the ease and silence with which the movements of a mirror are made render the employment of the heliograph preferable to the extreme difficulty of preserving the alignment of a lamp, and the noise of its screen or shutter. The light being stationary, signaling proceeds uninterruptedly without any fresh adjustment being necessary. But with the regulation lamp issued to regiments in India, if the stations are any distance apart, it is very hard to keep the lamp held constantly in the exact direction which gives the receiving station most light, and if there is much work to be done, a man's arm gets stiff from holding it so long in the same position.

It has often been advanced as an argument against the adoption of the heliograph, that it is useless without the sun. The argument is unanswerable, but even the telegraph line is not proof against weather. With the Kuram Column field telegraphs were laid on posts without insulators; dust soon filled the notches cut in the posts, and when rain fell the electric current was greatly weakened or entirely lost. The ground line laid by the Field Train, from exposure to weather, suffered in a like manner, for the gutta-percha covering being liable to crack, often on a rainy day the sounders in a telegraph office were as idle as the heliographs. But in a climate like India, it is surprising how few sunless days there are. Probably the proportion in a campaigning season would only be one in eight.

Clouds are of course a serious hindrance, and usually an effectual barrier to heliography, but to limited distances the flash from a mirror is capable of penetrating any ordinary haze, smoke, translucent clouds, or dust. In the Jowaki-Affridi campaign, the signal party at Peshawur were posted on the church tower; sometimes, owing to dust, haze, or smoke, the church became obscured to view, even through a telescope, and yet the signaling was uninterupted. On the 19th January, 1878, the Peshawur signalers were called up from the Tor-Sapar heights, distance 24½ miles, and through communication was then for the first time opened between the Peshawur and Kohat Valleys; yet on this occasion there was such a haze over Peshawur, that the outline of the church was hardly visible through telescopes.

The earliest reports speak to the penetrating power of the flash from heliographs tried between Shaikh-Bodeen

and Dehra Ismail Khan, distance 38 miles, although the weather was so hazy that the stations were barely visible.

Again, Lieutenant Savage, R. E., Superintendent Field Telegraphs with the Kandahar force, reports that on the 4th January, 1879, "Captain Bishop with General Palliser's advanced cavalry flashed us up at 11 A.M. from about 14 miles ahead, and a message from General Stewart was taken, which was sent on to him. Signaling party rode on several miles, and on receipt of answer, opened communication again and sent it; dust flying so thick that the hill on which the distant party was stationed was nearly invisible, but their flash was like a bright star through the dust."

Under such circumstances as these, no other visual signaling but that of sun flashing would have availed.

Circumstances may often arise when sun flashing would be very desirable, but no proper instruments are available. It may be as well, therefore, to mention that an impromptu apparatus, perfectly effective for temporary purposes, can be devised out of an ordinary shaving-glass in a few minutes. If two sighting points are aligned on the distant station, the glass can be directed truly and satisfactory signaling carried on by exposing and obscuring the flashes with a book or anything else at hand.

Selection of Signal Stations.—The selection of the best positions on which to establish signal stations in a strange country, during active operations in the field, is perhaps more difficult than would at first appear, the difficulty increasing with the distances to which the lines of communication extend. When stations are far apart and the configuration of the country monotonous, the ready appreciation of the best points of observation requires an eye for country and aptitude for locality which cannot be expected from all signalers. An officer should always be entrusted with this important duty; also when there is a press of work at an intermediate station, the presence of an officer is essential to ensure the regular and rapid receipt and despatch of messages, for it often happens in such contingencies that signalers get disheartened when messages accumulate, and irregularities and delays are the consequence.

Sometimes it may be advisable to vary the stations, although still keeping up communication between the same signaling parties, for not infrequently the signal station is unavoidably some distance from camp, and more or less isolated and exposed. The fact of an enemy knowing that at a particular time and place he can rely upon finding a small body of men detached gives an opportunity for, and proves an incentive to, attack which might not be attempted under slightly altered circumstances.

If the country is hilly, and any difficulty is experienced in establishing communication for the first time between parties whose position is uncertain, delay might be prevented by the assistance of signal fires, heaping on damp straw or green brushwood in the daytime, so that a column of smoke would ascend which could be discerned for miles, and clearly indicate the whereabouts of each. As before stated, there is little or no trouble in sweeping the flash from a mirror over all the country within view, but in the case, say, of both parties being on low ground with hills between them, the foregoing plan might be advantageously employed.

Some delay took place in establishing the stations at Hazar Pir and the Peiwar Kotal, because the signal party at the former did not ascend high enough. They distinguished the outline of the long spur extending from the Sufed Koh over which the road runs, and thought they saw the Peiwar Kotal Pass, but the block of hills about the Darwaza-Gai interfered and obstructed the flashes from both parties until a higher line clear of them was established; the distance between the two was 35 miles.

Training of Signalers.—Too much care cannot be devoted to the training of army signalers, for it is when speed and accuracy can be relied upon that signaling proves so invaluable, and experience teaches that one is the accompaniment of the other. By the "Manual of Instruction in Army Signaling," a speed of five words a minute is necessary for qualification with flags, but it is found that the signaler who averages over seven words a minute is more correct than another who does not attain to that standard. With the heliograph a much greater speed should be insisted

upon, ten words should be the minimum allowed for qualification. From the earliest instruction signalers should be taught to work quickly, each letter being signaled at the uniform rate at which they will eventually be called upon to work; for beginners of course the pauses between letters can be regulated to suit the capacities of those under instruction, but if at first taught to signal and read slowly, they contract an imperfect style and disregard to time which is the essential of good signaling.

The training and practices should be made as interesting as possible, and all qualified signalers should have frequent opportunities of keeping up the knowledge they have acquired, periodical practice being necessary for a high state of efficiency. They should be exercised in detached parties sent out in different directions without any pre-arrangments, and instructed to find and open out communication with each other. During route marches, advance and rear guards should have signalers attached, whose duty it would be to avail themselves of every opportunity of communicating when advantages of ground offered. The men should be thoroughly conversant with the best kind of back grounds, which differ materially for heliographs and flags; for instance, a sky-line is the best for a flag, but the worst for a mirror. Careful consideration in the selection of back grounds will often save much time by avoiding the necessity of any subsequent alteration of the position taken up.

Staff of Signalers.—It would be almost impossible to lay down any hard-and-fast rule regarding the numbers of signalers that should accompany an army taking the field, so much would depend upon the nature of the country to be traversed both geographically and politically, and the disposition of the troops. In every instance the requirements would be subject to constant variation, and although 20 signalers might in some cases suffice for a force of 5,000, it is quite certain that the proportion this would give of four to a thousand would be inadequate. Roughly speaking, taking the numbers with the Khyber, Kuram, and Kandahar Columns during the first phase of the Afghan campaign, the proportion of signalers to fighting strength was as 1 to 250.

A memorandum from the Quartermaster-General's Office, dated Lahore, 11th December, 1878, states that "all the signalers are to be made over to the officer in charge of signaling, who will arrange for their pay, rationing, discipline, carriage, camp equipage, &c.;" this memorandum was issued after the force had crossed the frontier, and it was found impracticable, therefore, to carry out the instructions in their entirety. Lieutenant Savage, R.E., Kandahar Column, reports: "with this force the signalers have seldom been detached altogether from their regiments . . . . they are more comfortable than when entirely detached."

Perhaps a compromise between the two would answer best. There might be a permanent staff consisting of specially-selected expert signalers in the proportion of say 1 to 300 entirely under the signaling officer. He, however, would be in possession of the names and qualifications of all the other certificated signalers with the force, so that at any time when extra work had to be done, signalers could be drawn from regiments and detachments on the spot, who without being removed from their companies, could, for the time, give their services, and receive their signaling pay according to the periods of employment. It is very desirable not to withdraw men from the fighting strength of regiments unnecessarily, and this would often be the case if a sufficient number of signalers to meet all contingencies were kept as a permanency on the signaling staff.

Pay of Signalers.—During the Afghan campaign, the Government of India sanctioned extra pay to signalers, at the rate of eight annas for non-commissioned officers, and six annas for privates, per working day. This was most desirable, for not only were they generally kept employed, but the wear and tear to clothing and boots greatly exceeded that of their comrades. If not actually at work, they always had to be at their posts, for the success of signaling operations depends upon the careful look-out, kept so as to ensure a signal from any direction being promptly responded to. Formerly, then, it can hardly be wondered at that the position of a sig-

naler was not much coveted, but now that they receive remuneration, a high standard of efficiency should be exacted before a man receives a certificate of qualification. The responsibility of their duties should be impressed on them, and the strictest observance to the regulations laid down for the conduct of a signal station should be enforced. None but really first-rate signalers, and fairly educated men, should be entrusted with the charge of a station.

The heliograph does not yet form part of the signaling equipment of regiments at home or in the Colonies, and being of comparatively recent issue to those on the Indian Establishment, men are borne on the Signaling Rolls of their regiments irrespective of their knowledge of that instrument, and it happened when signalers were called for, some were sent to the front who had never been trained with the heliograph, and until they were taught their services were of little or no use. It is not a case of two heads being better than one, for one good signaler left entirely to himself will get through more work than half-a-dozen indifferent ones.

Mounted Signalers.—When troops are on the line of march mounted signalers should always be held in readiness and placed as circumstances may require, for in the event of any communication being necessary between, say, the advanced and rear guards or flanking parties, by the time Infantry Signalers had opened communication and despatched whatever business there was, the column would have moved on and they would be unable to regain their places without much fatigue, whereas cavalry men could push from point to point with ease and rapidity. They might also be most advantageously employed when a signal station happened to be some distance from camp, for not only would the dismounted signalers be saved harassing marches to and fro, but communication would be opened earlier of a morning, which is a desideratum. The brightness of the sky and power of the sun in the forenoon should be utilized to the fullest extent, for in a climate like India, just double the amount of work can be got through in the morning as is possible in the evening. Generally speaking, the sky becomes more or less cloudy after one o'clock, and stations bearing west appear surrounded with haze.

General Biddulph strongly advocates the employment of mounted signalers. With the Peshawur Valley Field Force signalers from a cavalry regiment accompanied all reconnaissances. From the 20th to 23rd March, 1879, they rode out to a height about four miles from Jellalabad and kept up communication between General Browne's head-quarters and General Tytler's force, which was destroying the towers of recalcitrant villagers in Maidanak. Again, on the 26th December last, a brigade marched from Cabul to Mir Butcha's forts in Kohistan, and by sending out a cavalry signaling post daily to the hills north of Sherpur communication was maintained with the brigade, although two ranges of hills separated them from the capital.

Screening Heliographs.—The work at a signal station is naturally subject to constant fluctuations, and it is when a number of messages pass along the line that the strictest superintendence becomes necessary, for if everything is not in good working order and discipline not enforced, the sun sets before perhaps half the messages have been despatched. Heliographic signaling requires the greatest patience. This should be im pressed on men under instruction, for they are certain to have their forbearance and tempers put to the test. Either the light fails at a critical moment—the reader at the opposite station requires constant repetitions—he, in his turn, does not give the most favorable flash to read by—and so on; it is astonishing how many interruptions do take place, but practiced hands soon get accustomed to such vexations, and learn the value of time. However, notwithstanding every forethought and supervision, the press of messages is sometimes too great for the ordinary single line of heliographs, and when this is the case and the instruments are available, they should be doubled. This was done when General Roberts visited the Peiwar Kotal in February, 1879; the telegraph line was only then laid as far as Habib Kila, so a couple of instruments were set up at each station, one for despatching, the other for receiving messages, and by this means just double the amount of business was transacted as would other-

wise have been possible. To avoid confusion, the heliograph despatching was screened from the party despatching from opposite station and *vice versa;* the men reading at one station were not interrupted by seeing the answering flash of the party receiving at the other. A tree, rock, or the gable end of a hut became available to screen the instrument.

The flash from a heliograph is a reflection of the image of the sun and consequently has an angular diameter of 32′. The diameter of a disc of light increases with the distance from the mirror. At 107 yards the disc is one yard in diameter, and theoretically should increase one yard in every 107, but practically it will be found to increase very much more. This proportion would give only about 66 yards for a range of four miles, but the flash has been seen at that distance for 100 yards on either side of the signal station. Thus it might be necessary, in the event of an enemy being likely to decipher the signals, to screen the flashes from his view, and as this requires a little nicety it should form part of the instruction of signalers. On the other hand, the flash may have a discouraging effect on an enemy. It was generally considered by the Affridis that the heliograph was a mystic instrument by which homage was paid to the great Sun-God, his favor invoked, and the light of his countenance prayed for. This superstition was confirmed to their minds by the fact that snow, which usually falls in November, held off till February and extraordinarily fine weather prevailed, favoring the movements of troops and facilitating the collection of stores to an extent which, under ordinary circumstances, would have been impossible. And in December last when the Cabul force was temporarily shut up in the Sherpur cantonments, surrounded by the largest number of fighting men that have ever been assembled in those parts, heliographic communication took place between the garrison and Colonel Hudson's small force at Luttabund. The flash must have been seen by many of the tribesmen, warning them that the connecting links with the Khyber Division were still intact, and that the reinforcements would soon be pushed forward to put to flight Mahomed Jan and his followers.

In connection with the subject of screening flashes, it may be well to mention that when three signal stations happen to be nearly in a straight line and are all at work, the terminal stations will possibly be much inconvenienced by observing the flashes from two mirrors. A case of this kind occurred in the Kuram Valley last year. The Peiwar Kotal signalers worked with Habib-Kila and Kuram, both of which, although 12 miles apart, had the same bearing. The Kuram signalers could see the sheen of the mirror working to Habib-Kila as well as the flash of that directed on them. This was rectified by screening the heliograph from the station for which the messages were not intended.

Signal Fires.—There can be no doubt that the hill tribes of the N. W. Frontier carry on communication by signal fires. These beacons can be seen for such vast distances that it is possible the revolt which took place at Herat the day following the massacre of the embassy at Cabul was pre-arranged, and that the temporary cessation of British influence at the capital was by some preconcerted signal communicated across the hills.

It would be interesting to know if they have any particular code. Probably their signals are very limited and just arranged for the time being, still any system by which the simple intelligence "all's well" or the reverse can be communicated, is worthy of attention, and until a great improvement in the lamps in use with regiments takes place* signal fires might often be resorted to with advantage.

A curious case of night signaling was watched on the arrival of General Roberts in the Khost Valley in January, 1879. The Ameer's representative, Naib Akhram Khan, held the Matun Fort with levies which were not at first removed. The ex-Governor of Khost, with the usual treachery and dissimulation of his race, had assured the General that all was quiet and that the inhabitants were looking forward with joyful expectancy to the British Raj. During the first night a torch was carried round the ramparts presumably to acquaint Mongals and Khostwals that they still retained pos-

* Lieut. Whistler Smith, R. E., Superintendent Field Telegraph, reports that his experiments with Begbie's (C) pattern lamp were successful up to 25 miles.

session of the Fort, and Flashes, as if a handfull of gunpowder had been thrown on to a fire, were answered in a similar way from the hills. The events of the following day gave additional proof of the character for which the Afghan is so proverbial. No supplies had been furnished, and a cavalry reconnoissance drew the enemy, who were harbored in the surrounding villages. They sallied out on three sides of the camp, and as it afterwards transpired, looked upon the annihilation of the force and the general looting of the camp as a certainty. The tribes between the Khost and Kuram Valleys were ready to close the communications and actually seized a cavalry outpost at Yakoobi. It is needless to say that their schemes were frustrated.

Heliographic Chart of India.—It is probable that no perfect heliographic system could be established connecting the stations scattered over the plains of India, the country is so flat and the lower strata of the atmosphere as a rule so dense and murky, but there is no reason why the stations within view of the hills might not be connected, by making use of carefully selected points in the hills as intermediary; stations in the plains invisible to each other might thus be brought into communication. This would especially be the case in the Punjab and parts of the N. W. frontier. Signals between Chakrata (in the hills) and Roorkee (in the plains) have been read with the naked eye, and as they are 60 miles apart it is not improbable that with the aid of good telescopes many of the principal military stations could be connected. When opportunity offers it might be as well perhaps to institute practical experiments and have a clearly defined scheme drawn up which would bring as many as possible of the more important points into communication, so that in the event of any interruption in the telegraph line, the alternative means could be resorted to without delay.

The "Heliostat."—In the "Army Signaling Manual" an instrument called the heliostat is described, which differs from the heliograph chiefly in this particular only, viz., that instead of making the appearances and disappearances by a slight alteration of the mirror they are affected by raising or lowering a shutter which exposes and hides the reflecting surface. It is evident that this is a slow and laborious process in comparison with the rapid and simple motion occasioned by the slight pressure of a signal key. The reason for this modification of Mr. Mance's original instrument is that the action of the finger key disturbs the tripod, and alters the alignment. I can confidently say that during the whole time I have worked with the heliograph, and I have done so on every variety of ground, no such difficulty ever presented itself. If the instrument is properly set up, the alignment is easily made and as easily preserved, and the motion of the mirror either in signaling or adjusting does not interfere with it.

Conclusion.—It will be evident from what I have said that army signaling is likely to play a much more important part in warfare than has hitherto been the case. However old the use of mirrors may be for flashing, their employment for conveying verbal intelligence is of quite recent date. We hear nothing of heliograph messages in the American Civil War, the Prusso-Austrian, the Abyssinian, the Franco-German, or the Turko-Russian Campaigns, and we may perhaps accept this as sufficient proof that no such instrument was then in use. During the last two or three years, however, the heliograph has proved of such incalcuable value that its importance cannot be overrated. The evidence brought forward here may perhaps induce my hearers to concur in the opinion that the subject is well deserving the serious attention of the authorities, in order that the service may be provided with the best possible equipment, and army signalers encouraged to make themselves proficient in the art of heliography.

APPENDIX.

Notes on Construction of Signaling Apparatus.—A few remarks on the signaling apparatus and the component parts of heliographs may not be out of place.

Nearly all the instruments used in Afghanistan were of the regulation Roorkee pattern varying in details according to the date of issue. The mirrors ranged between $4\frac{1}{2}''$ and $5\frac{1}{2}''$ in diameter. Each column had in addition a $3''$ instrument supplied directly by Mr. Mance, and it was worked most suc-

cessfully between the Peiwar Kotal and Ibrahimzai—distance 30 miles. The tripods were, however, too light to withstand wind and rough usage, but in accordance with recommendations made at the time, they have since been constructed more substantially with metal plates strengthening the joinings of the legs with the center piece.

So many sizes and patterns have now been tested that it would be well if steps were taken to decide upon the most desirable. While, undoubtedly, the 5″ heliograph is the best adapted for general use, it would appear advisable that a proportion of 3″ instruments weighing only about as many pounds as should be available for reconnoitering parties and mounted signalers, and 8″ or 10″ for distant signaling. When the question has been carefully considered, great exactness should be observed in the manufacture of all the component parts so as to render them interchangeable. Some of the instruments in use with regiments in India were made at the Sappers and Miners Workshops, others at the Roorkee Canal Foundry, and the fact of the mirrors and various parts not being similar was often the cause of much inconvenience.

Sighting Arrangements.—When the heliograph was in its infancy, a sighting rod was set up about 10 yards in front of the instrument, and fitted with a metal stud which slid up or down until truly aligned with the distant station. In communicating, the flash was kept playing on the stud. This sighting rod was abolished in favor of a tripod, which serves to support quite a new form of sighting rod (or, when the position of the sun demands it, a reflector which is ingeniously adapted to serve also as a sighting vane). This second tripod is placed about 3 feet from the signaling mirror tripod; being made to interlock, both can be carried when packed as easily as one. But the instruments now issued to regiments in India are provided with a supporting arm which dispenses altogether with the second tripod. This arm, about 16 inches long, is clamped to the base of the instrument and serves to support the sighting rod, or, when occasion requires it, the reflector. The points for and against a supporting arm may be summed up as follows:

It dispenses with one tripod, consequently is more handy, saves a little in weight, and practically wherever a man can get a footing, the single tripod instrument can be set up. On the other hand it is alleged that a high wind driving against a mirror, placed at the extremity of a projecting arm, occasions a vibration that affects the steadiness of signals, as it makes the instrument top-heavy; a short arm necessitates placing the mirror at a less favorable angle for catching the sun, and thus causes loss of reflecting surface, while a long one increases the vibration, and, what is of more importance, adds largely to the size, weight, and cumbrousness of the box in which it is carried. The time required to set up and repack would probably be a little less with the supporting arm.

Horizontal Motion Screw.—For a long time the horizontal motion screw of the instruments manufactured in India was fixed to the signaler's right. This was well enough for a left-handed man, for he could regulate the flash with his right hand by turning the screw as the sun apparently worked round, while he signaled with his left. But as left-handed men are the exception, the position of the screw was condemned, and in the more recent issues, just before the Afghan campaign commenced, the screw was on the left hand side, thus suiting all right-handed signalers. In Mance's 3-inch heliograph (and I understand in all his instruments) the revolving plate and horizontal motion screw are so constructed that the screw can be placed right or left, which is of course a great advantage. This is effected by fixing the screw to the metal piece which fits on the tripod, and not to the base of the mirror. In the Roorkee patterns, the screw turns itself as well as the mirror round the tripod.

Mirrors.—Various methods have, from time to time, been adopted in India of securing the mirrors to their frames. When breakages occurred, it was remarked that those which were fastened with screws connecting the rim and frame, generally cracked from screw to screw, showing probably that the glass was pinched at those points. Some heliographs received from the Roorkee Canal Foundry had the mirrors secured with-

out screws, a tight-fitting rim over the mirror seemed to keep it firmly fixed in the frame. Mr. Mance puts the mirror in at the back, padding it with a few slices of cork and then screwing on the thin backing of metal which rests on a flange in the rim and does not touch the glass. With this arrangement breakages are said to be extremely rare.

While on the subject of mirrors it may be useful to remember that glass can be cut under water with a pair of scissors. Spare mirrors were ordered to be sent to Kuram, but no mention was made in the indent that they were required for heliographs with screws fastening the mirrors between frames and rims. The mirrors arrived and the edges had to be cut to allow the screws to pass through, this was done by holding the glass under water and cutting it with a pair of scissors.

Telescopes and Stands.—A really good telescope and strong serviceable stand ought to be issued to regiments for the signalers, who should be practiced in their use and taught to read signals at long distances. As a rule, men strain their sight by trying to read with the naked eye instead of using a telescope, and a man is constantly seen delaying over his message by calling for more "light," when with the aid of a telescope he could read straight through without an interruption.

With the Kuram Force, the telescopes and stands were of all sorts and sizes, some large and cumbersome, others small and fragile; with regard to the telescope stands there were none that answered the requirements of supporting the telescope firmly in position and with the means of speedy adjustment in any direction. As a rule the men had to improvise rests, or place the telescope on rocks. It is very important that a signaler should be able to settle down comfortably at a telescope steadily fixed, when reading messages.

Sighting Vane.—The sighting vane proved the weakest part of the heliograph during recent trials on field service. The cross edges constantly became disconnected from the circular rim. The chains to which the silver discs were attached broke, and the discs were lost. It was difficult also to adjust the discs when the man's hands were cold. The sighting rod with the instrument supplied by Mr. Mance was far preferable, no part of it can be lost. The alignment is rapidly altered, for, being jointed, the vane can be raised or lowered or moved to the right or left, without shifting the tripod. The aluminium disc is permanently fastened to a strong steel shaft, and is of sufficient length to enable the signaler to see the shadow spot when the key is not depressed, *i. e.* the rise and fall of the shadow spot can be plainly seen while signaling.

Fastening of the Signaling Key to Frame of Mirror.—The signaling key in the Roorkee pattern is attached by a piece of metal and small screws to the frame of the mirror; these are quite unequal to the strain, and soon work loose. It should be screwed to the circumference of the frame where there is more metal to receive the screws.

Boxes.—All reports agree that the heliograph boxes are not sufficiently strong, and the cleats inside for securing the instrument, supporting arm, and sighting vane, sometimes broke or dropped out, but these and all other defects of the kind will no doubt be attended to in future.

Mance's cases are constructed to serve as a stand for the instrument, should the situation render it more expedient than the erection of the tripods.

Spare Component Parts.—The officer in charge of any signaling operations in the field should have a case fitted with spare mirrors, screws, springs, &c., and a few simple tools. Sometimes, for the want of such appliances, an instrument had to be sent to Roorkee for repair at a time when it could probably ill be spared.

Colored Spectacles.—A few colored spectacles should be provided, for the constant strain of reading signals when there is a glare or high wind is very trying. But signalers are not sufficiently careful of their eyes, and especially when using a telescope, they generally press the eyelid and eyeball of the closed eye with their fingers when looking through a telescope, instead of simply screening it with the hand hollowed in such a way that no portion of the eye experiences any pressure. They ought to practice reading right and left eyes alternately, so that the strain may not always be on one.

Message Books.—The new form of message book, with a division ruled for each letter, was universally condemned and the old pattern procured when possible; the signalers found great difficulty on a cold morning in keeping the letters within their limits and the messages were always more difficult to read than if they had been taken down in the ordinary manner.

THE power of absorption of heat rays by powders not mixed with any binding material has formed the subject of investigation by Herr Van Deventer. Under a copper cube kept at 100 deg. was brought a thermo-element consisting of a brass plate, on the lower side of which was soldered a parallelopiped of bismuth and antimony. On the plate was spread the powder to be examined. A second similar element, with thermo-element lampblacked, served for control. The results were: (1) Powdered substances in the same physical state have different absorptive power; (2) this depends on the thickness of the absorbing layer: each powder has its maximum absorption layer; (3) quite comparable values for the absorption cannot be had, as the thickness of the powder layer cannot be exactly determined; (4) the divergences proved in Tyndall's results with different binding materials are attributed to his not having taken into account the maximum emission layer; (5) whether the binding material affects absorption, and if so, how can it be demonstrated by the author's method—the element being painted over with the liquid holding the powder in suspension—but experiments are here wanting; (6) the author's series of powders arranged according to absorption is quite different from Tyndall's emission series.

EXPERIMENTS ON THE RESISTANCE TO HORIZONTAL STRESS OF TIMBER PILING.

By JOHN WATT SANDEMAN, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

THESE experiments were undertaken to ascertain the amount of resistance opposed to the horizontal movement of timber piling by different strata, such as clay, sand, and forced material; also to determine the length necessary to be provided for, in back tie or anchor piles, with a view to economy in the construction of an extensive amount of river quayage. The results are recorded as affording a few practical data for elucidating these questions, in reference to which, so far as the author is aware, no experiments have hitherto been made.

For each experiment two piles were driven (Figs. 1 and 2) at distances of 20 feet apart, and slightly inclined from the vertical; one representing the front, and the other the back tie pile in an ordinary timber quay. The front piles were securely strutted to resist horizontal stress, the lower ends of the struts abutting against short piles. The back piles were free to move towards the front piles under the influence of the stress. The horizontal movement was measured from a plumb line at the levels indicated (Figs. 3 to 10), which show the inclination of the back piles in each case previous to the application of any stress. The measurements recorded in the lower columns of the table do not, however, represent the total distances through which the back piles moved. The actual distances at the same levels would probably be at least twice those given in the table, dependent on the depth below the ground at which any movement of the piles took place. In experiments Nos. 2 to 5 the back piles were pulled beyond a vertical line, as indicated by the horizontal measurements in the table being greater than those in Figs. 4 to 7.

The stress was applied at different levels between the piles by chain blocks and fall attached to each, the loose end of the chain being fastened to smaller blocks with a rope fall, the end of which was conveyed to a winch. The stress was registered by one of Duckham's 20-ton hydrostatic weighing machines.

The square piles were of Baltic red pine, the round piles of English forest larch.

TABLE SHOWING THE RESULTS OF EXPERIMENTS ON THE RESISTANCE TO HORIZONTAL STRESS AFFORDED TO TIMBER PILING BY DIFFERENT SOILS, ETC.

	Stress applied above Ground level	Stress applied near Ground Level.					Stress applied below Ground Level.	
	Experiment No. 1. Square Piles.	Experiment No. 2. Round Piles.	Experiment No 3. Square Piles.	Experiment No. 4. Square Piles.	Experiment No. 5. Square Piles.	Experiment No. 6. Square Piles.	Experiment No. 7. Square Piles.	Experiment No. 8. Square Piles.
Nature of ground.....	Clay	Loose ashes & clinkers	Ashes & clinkers to depth of 12′, hard ground below	Clay	Clay	Sand	Clay	Clay.
Length and diameter of piles...........	24′3″ × 12″ × $12\frac{1}{2}$″	26′ × 12″D. at ground level	20′ × $12\frac{1}{4}$″ × 12″	24′ 3″ × $11\frac{1}{2}$″ square	16′ × $12\frac{1}{4}$″ square	24′ 6″ × $12\frac{1}{2}$″ square	25′ × 12′ square	15′ 6″ × 12″ × $11\frac{1}{2}$″.
Inclination of pile.....	1 in $10\frac{3}{4}$	1 in 29	1 in 12	1 in $10\frac{3}{4}$	1 in 12	1 in 9	1 in $11\frac{1}{4}$	1 in $12\frac{1}{2}$.
Depth of pile in ground	15′	18′	15′	15′	10′	14′	(Original) 15′ (Forced) 5′6″	(Original) 10′. (Forced) 5′ 6″.
Height of pile above ground...........	9′ 3″	8′	5′	9′ 3″	6′	10′ 6″	(Original) 10′ (Forced) 4′6″	(Original) 5′ 6″. (Forced) 0′ 0″.
Level at which stress was applied, + above, − below, original ground.....	+ 6′ 6″	About + 6″	About + 6″	About + 6″	About × 6″	About + 6″	About + 6″ & − 5′ forced	About − 2′ and − 7′ 6″ forced.
Length and breadth of planks on back piles	....	....	....	....	....	....	Two planks 10′ long and 9″ wide	10′ long and 5′ 6″ in total width.
Position of planks.....	....	....	....	....	....	....	+ 5′ 6″, covered by forc'd material for 8′ in length	Top + 5′ 6″, fully covered by forced material.
Nature and depth of forced materials heaped against planking on back piles..............	....	....	....	....	....	....	Sand and ashes 5′ 6″ deep, and extending 9′ in front of piles	Sand and ashes 5′ 6″ above and 3′ below ground level, and extending 10′ in front of piles.*

* A trench 3′ deep was excavated in the line of the piles, to enable the stress to be applied lower.

The numbers in the columns below indicate the movement in the back piles under the influence of the stress, measured in inches, or described in the Paper.

Stress in Tons.	1st Trial.	1st Trial.	1st Trial.	2d Trial.	3d Trial.	1st Trial.	2d Trial.	1st Trial.	2d Trial.	3d Trial.	4th Trial.	1st Trial.	2d Trial.	3d Trial.	4th Trial.	1st Trial.	2d Trial.	1st Trial.	2d Trial.	3d Trial.
1	1¼	1⅛	..	..	..	..	..	⅛	..	..	..	..	..	..	..	..	1¼	..		..
2	2⅜	..	..	..	..	⅛	..	¼	..	..	..	⅛	..	..	..	..	,,	..		..
3	3	1¼	⅛	..	..	⅜	..	..	..	..	..	..	..	..	..	..	,,	..		..
4	Upon increasing the stress beyond 3 tons the pile yielded, and came out of the ground so easily as to prevent the continuance of the experiment.	1⅞	¼	..	..	¾	..	⅜	..	..	..	¼	..	..	..	..	1⅝	⅛		..
5		..	¾	..	..	1	4⅜	½	..	..	..	⅜	½	..	..	¼	1⅞	,,	Pile bent 1⅛″ at ground level.	⅜
6		3½	1⅜	2¼	5	1⅜	..	⅝	..	..	..	½	⅝	..	..	..	2	,,		Pile bent 1¼″, which caused amount of forward movement to vary.
7		6	3¼	2½	..	1¾	..	⅞	..	5½	..	⅝	¾	..	..	..	2¼	,,		
8		11	..	3¼	5⅛	2⅜	4⅝	1¼	..	..	..	¾	⅞	..	..	1⅛	2⅜	,,		
9		After 8 tons stress the pile came away so easily that no more stress could be applied.	..	4½	5¼	2⅞	4⅞	1⅞	2⅞	5¾	..	..	1	..	..	1¼	2¾	,,		
10			..	..	5¾	3¾	5	..	3¼	6⅛	..	..	1⅛	..	..	1¾	3⅛	,,		
11			With 11 tons stress the pile broke off at 5′ 5″ below the ground level.			4⅜	5¼	..	5⅛	..	8½	..	1¼	..	..	2¼	3⅗	,,		
11½						..	..	..	6½	..	..	..	..	..	..	..	..	,,		
12						..	7⅛	..	..	7⅛	9¼	..	1½	2½	..	2¾	4½	,,		
12½						..	..	..	..	8¾	..	..	..	..	..	..	..	;;		
13						With 13 tons pile broke off at 5′ 2″ below the ground level.		..	..	..	10	..	1⅝	..	..	With 13 tons stress the pile broke off at about 5′ below the ground level.		⅛		
13½								..	..	..	12	..	..	..	..			..		
14				....				After 13¼ tons the pile yielded so much that no more stress could be applied.				..	1⅞	2⅝	..			..		
15		....		....								..	2⅛	2¾	3⅛			..		
16		....		....								..	2½	2⅞	..			..		
17	....	....		....								..	2¾	3	3¼			..		
18	....	....		....								..	..	3¼	3⅜	....		..		
19	....	....		....		....						..	..	..	3⅝	....		..	⅛	
20	....	....		....		....						..	..	..	4	....		..	¼	¼
(Probably) 23	....	....		....		....		....				When stress reached 20 tons it was removed, & the pile resiliated 1⅜″.				....		..	⅜	½
Weighing machine did not register above 20 tons, but index hand went beyond it.																		No more stress could be registered by machine.		

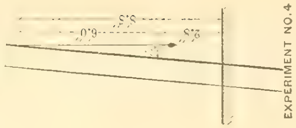


Fig.6

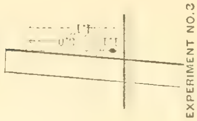


Fig.5

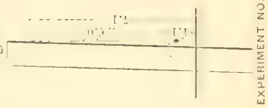


Fig.4

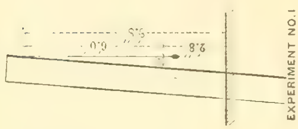


Fig.3

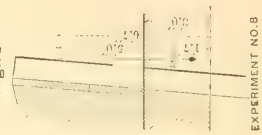


Fig.10

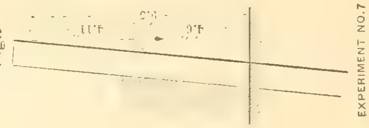


Fig.9

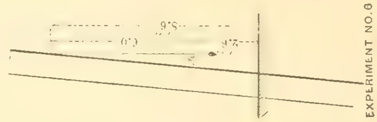


Fig.8

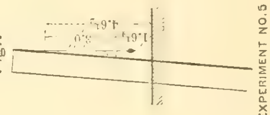


Fig.7

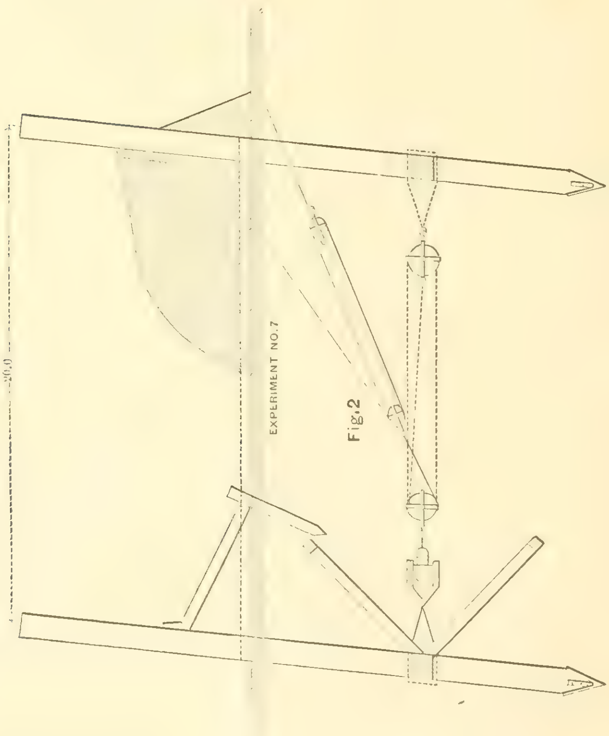


Fig.1

Fig.2

The following data are afforded from the results of the experiments :

First. The amount of resistance opposed to the horizontal (or partially radial) movement of timber piling by different natures of ground.

Second. The variation in the amount of resistance which different strata oppose to horizontal movement—loose ashes affording the least, clay more, and sand the greatest amount of resistance, as instanced by experiments Nos. 2 to 6.

Third. The amount of increase in the resistance to horizontal stress obtained by planking upon tie piles, instanced by comparing experiments Nos. 4 and 5 with experiments Nos. 7 and 8.

Fourth. The length necessary to be provided for in back tie piles.

From the fact that three piles (experiments Nos. 3, 4 and 7), driven 15 feet into different strata, broke off at about 5 feet below the surface of the ground, it may be inferred that a tie-pile at a depth of about 15 feet into the ground would meet with as much resistance to horizontal stress (applied at the level of the ground) as if the pile extended to any greater depth.

THE DEPHOSPHORIZATION QUESTION.

From "Iron."

The visit of the Iron and Steel Institute to Düsseldorf, and the opportunities generously afforded the members of observing the working of the Thomas-Gilchrist process at the Rhenish Steel-works and at Hoerde, have naturally tended to increase the interest felt in the important question of dephosphorization. It will, therefore, not be out of place to review briefly the present relative position of the basic and the acid processes, which are about to engage in a severe and protracted struggle—the one for supremacy, and the other almost for existence.

As Professor Tünner said, the chemical problem has been definitely solved, and although chemists may differ as to the exact course of certain reactions, the fact remains, that with proper care and attention, what has hitherto been regarded as the commonest of forge pig may be converted into good steel by the Bessemer process. If there were no greater difficulties in the manipulation of the basic than of the acid process, the immediate future of the old Bessemer trade would be very gloomy. As far as can be seen at present, however, certain conditions must be strictly observed in carrying out the former, in order to insure uniformity in the quality of the metal produced; and these conditions cannot be fulfilled without incurring extra expense. It is, no doubt, probable that, in the course of time, material reductions will be made in the working of the process; but, still, it must be confessed that there is no likelihood that, given a phosphoric pig on the one hand, and a non-phosphoric pig on the other, at the same price, steel will ever be produced as cheaply from the former as from the latter. This being so, the question may be stated as follows:—Can the cost of hematite pig iron ever be so reduced that the difference between it and the cost of phosphoric pig shall not exceed the extra expense of converting the phosphoric iron? The advantage of the new process is entirely centered in the cheapness of the raw material, and, therefore, needs no further comment. Its disadvantages demand more careful examination.

Mr. Massenez concluded the valuable paper which he read before the Institute by enumerating some of the items to which special attention must be paid in carrying out the basic process—at all events with white iron, which, he says in another place, "is, for many reasons, the most suitable quality." The first of these items is—Hot melting in the cupola. That is, the iron must enter the converter in a thoroughly fluid condition. In second melting there will, of course, be no difficulty here; but how will the direct process be affected, the advantage of which, in point of economy, is now

almost universally admitted? It was stated at the Düsseldorf meeting, that a special pig made expressly for the basic process, and containing scarcely more than traces of silicon, but nearly three per cent. of phosphorus, and over one per cent. of manganese, ran very hot from the blast furnace; but we must be allowed to express considerable doubt as to white pig iron running with the requisite fluidity, unless it contains a very appreciable quantity of manganese. The fluidity of the pig is a two-fold necessity; in the first place, to enable the blast to pass freely through the metal in the early stage of the process; and in the second place in direct working, to avoid heavy skulls in the ladle, which would be a very serious source of waste. It frequently happens, as any one acquainted with the routine of an iron-works will admit, that a stoppage or hitch occurs between the tapping of the metal into the ladle and its transfer from the ladle into the converter. With ordinary hot Bessemer pig a stop of half an hour matters comparatively little; but with white iron containing even 3 per cent. or $3\frac{1}{2}$ per cent. of phosphorus and manganese, such a delay would be far more serious. If, however, an average of 1.5 per cent. of silicon could be allowed in a pig of medium grayness, this difficulty would doubtless disappear to a considerable extent. But silicon, in the basic process, must be considered as great an impurity as phosphorus, if not more so. If direct working has to be abandoned, it will prove a very serious drawback to the new process. The other items to which Mr. Massenez draws attention, viz., the addition of hot, well burnt, lime, and an increased pressure of blast tend to augment the cost; but they present no technical diffiulties. It is also generally thought that the basic process will, for producing the same grade of steel, require a larger proportion of spiegel or ferro-manganese, and with this must be associated the reincorporation of a certain quantity of phosphorus reduced from the slag, the removal of which before the addition of the spiegel, has not yet been satisfactorily carried out. Any overblow, *i. e.*, any prolongation of the afterblow beyond the exact point, will result in the development of a larger amount of carbonic oxide on adding the spiegel, and as a natural consequence, the danger of further reduction of phosphoric acid will be increased.

We will next consider the question of sulphur, which, in the present phase of the process, seems to be its greatest enemy. Sulphur is no doubt eliminated in a great measure, and the course taken by the sulphur line, sketched out on a diagram, is somewhat similar to that taken by the phosphorus. No trace is eliminated until the process is far advanced; in fact, it first of all increases in proportion to the metal as other impurities are diminished, and even when the afterblow is completed, there still remains in the metal a very appreciable quantity—about one-third of the original amount. In two charges, quoted in Mr. Massenez's paper, the actual proportions were 31 per cent. and 33 per cent. Mr. Thomas, in the course of the discussion, gave 0.4 per cent. of sulphur as the margin, which should not be overstept in the pig. Now, although very good rails may be, and in fact are, constantly rolled with 0.13 per cent. of sulphur; still, for the higher qualities, such as boiler plate, so large an amount could hardly be tolerated; at least such is the opinion that has frequently been expressed at the meetings of the Iron and Steel Institute, by gentlemen who have been foremost in promoting the use of steel in engineering work. There are two ways in which the sulphur difficulty may be met; and it is simply a question of cost. Firstly, by reducing it in the blast-furnace and, secondly, by overblowing the metal. Practically speaking, lime alone will scarcely suffice to eliminate the sulphur in the blast-furnace—when working on white iron—and another agent, manganese, will have to be called into play. It is not for one moment denied that the sulphur can be got rid of by surcharging the burden with lime; but blast-furnace managers will agree that a highly basic slag, such as would be required, would, in the face of the low temperature necessarily prevailing in the production of white pig, be a constant element of trouble in the working of the furnace. The blast furnace is always subject to slight variations, from causes too well known to need enumeration. In the manufacturing of gray pig we have

always a margin of temperature, but in making white we have not, and any unforseen stoppage of stove or boiler power might, with a highly basic slag, lead to difficulties of a serious nature, more especially with the direct process. In all probability, therefore, the extra cost of a small proportion of manganiferous ore will have to be faced in those districts, such as Cleveland, where the iron ores do not contain an appreciable quantity of this element. As regards the overblow (as distinguished from the afterblow) the sulphur can doubtless be removed in this manner; but this involves a loss of yield, combined with an increased proportion of spiegel, which further adds to the danger of reabsorption of phosphorus. The former course seems, therefore, far simpler, and certainly cheaper, and is the one which will probably be followed.

In addition to the points already mentioned we have to take into consideration the extra cost of the basic lining, basic additions, increased dead charges, &c., arising from reduced make, or the alternative of more extensive plant, to turn out an equal amount of work. At present, Bessemer pits, where the basic process is in operation, do not work continuously; but only by day, for instance, the night turn being occupied in repairing—such was the case at the Rhenish steel works—or, as Mr. Thomas admits, with present appliances, a vessel must stop for two or three days every fortnight or three weeks to undergo the necessary repairs. It would, however, be manifestly unfair to charge the new process with all this cost, because when new plant is brought into operation, arrangements will be made for changing the vessels as required, which, will of course increase the charges on account of capital, although to a far less extent than those incurred by the use of existing plant. Professor Tünner, who has given much attention to the economical side of the question, estimates the extra cost, taking the average of the Austrian works, at about 20s. per ton; but for England this estimate is probably far too high, and as far as the items here involved are concerned, something between 12s. and 15s. per ton will probably be nearer the mark—according to local circumstances. But in Professor Tünner's estimate there are two points which are not mentioned, viz., the difficulties in the way of running the iron direct from the blast furnace, and the cost involved in keeping down the sulphur, which will have a material influence on the ultimate result of the process. The probability is that the basic process will be a far greater success on the Continent than in England. In Westphalia, where the interest is at present centered, there exists ores containing both phosphorus and manganese, and which will be more suitable for the production of the new Bessemer pig than Cleveland ore, and in Westphalia and the East of France, the difference between the cost of hematite and phosphoric pig is considerably greater than in England.

South Wales, however, with its chead fuel, and Barrow, with its cheap ore, should be able to withstand the attack of the new process for many a long day. As the success of the new method increases, so will the value of pure ores decrease. Spanish ore has been sold in Bristol Channel ports at very little over 13s. per ton, and Algeria, with its marvelous deposits of the richest and purest ores, and with the improvements that will certainly be made in the development and working of the mines, and in shipping accommodation, will, when the pinch comes, be in a position to supply the South Wales ports at far lower prices than have ever yet been reached. That the Thomas-Gilchrist process will, in course of time, become practically successful in some districts scarcely admits of a doubt; but it will probably be many years before Barrow and South Wales cease to produce Bessemer steel in as large quantities as at the present time.

The method of managing railway wagons with hydraulic capstans, well-known in this country, has been definitively adopted in France by the Campagnie du Nord, after ten months' trial, at the station of La Chapelle. The system seems to have been only once tried before (at Bercy station), but was given up for reasons unknown. The *Sociétié Hydraulique* is charged with setting up the necessary apparatus, which is to be ready by the end of next month.

COMPRESSED STEEL.

From "The Engineer."

The paper read at Barrow-in-Furness by Mr. Davis, of Westminster, on the compression of steel by the Jones process, as carried out at the Edgar Thompson Steel Works, in the United States, attracted a great deal of attention. The process, as modified by Mr. Davis, has been adopted experimentally at the Barrow Steel Works, and other firms are also, we understand, fitting up plant to try it. The idea of compressing molten steel to get rid of gas bubbles is not a new thing. Many years have elapsed since Sir Joseph Whitworth first practiced the art; and in Styria, at Neuberg, elaborate machinery was fitted up, at least ten years ago, to compress steel by hydraulic pressure. The plant required has, however, hitherto been very costly, and grave doubts have been entertained as to whether any results, and what results were to be had. The Jones process, however, dispenses with costly plant and opens up new possibilities; and steel makers who might well hesitate to invest £20,000 in an experiment, do not hesitate at all to spend a twentieth part of that sum on a small high-pressure boiler, and a few score feet of copper and iron piping. It is said that the Jones process has been quite successful in America. It is also said that it has been successful here. The contrast between it and the Whitworth process is so startling, that it is difficult to frame any consistent hypothesis to explain what takes place in the ingot mould. When two such eminent authorities as Dr. Siemens and Mr. Snelus differ in their explanations of the theory of the process, it is not too much to say that much remains to be explained. In a word, steel which has always been the most puzzling metal in existence, is determined to maintain its character, and has presented the world with a new problem, which may remain for some time unsolved. Let us consider for a moment what the problem is.

Sir Joseph Whitworth maintains considerable reticence with regard to several details of the practical working of his process, but, broadly stated, that process consists in forcing down a plunger or ram, by hydraulic pressure, on the molten steel when in the mould. He employs very high pressures; as much as two tons to the square inch, and more. Let us, for the sake of simplicity, suppose that he is dealing with a cylindrical ingot 10in. diameter and 5ft. high. The total pressure applied to the top of the molten metal will be about 150 tons or 160 tons. This pressure will presumably be diffused through the whole ingot while it is fluid, and it may be assumed that if any gas bubbles existed in the fluid they would be compressed; but however much compressed, they would still retain some dimensions, and there would, accordingly, be small blow-holes left in the ingot. But in practice no such blow-holes are found. At the Barrow Shipbuilding Works is now being erected a very large lathe. It will weigh 120 tons complete. All the gearing and shafting in this lathe is of Whitworth's compressed steel. Last week we made a careful examination of this gearing, and it may be pronounced to be absolutely without a flaw or a speck. To the back of a large face-plate is bolted a ring, in one piece, of internal and external teeth. The ring is some 6ft. in diameter, and the teeth are about 7in. long and 2¼in. pitch. It is impossible to find a flaw in it; and the ring has been machined. The contrast between this gearing and that used by makers of traction and ploughing engines is enormous. It is well known that to get from Sheffield firms a cast steel pinion without holes in which the end of a pencil can easily be put, if not the finger, is very difficult indeed. But in this lathe, as we have said, the pinions and wheels alike are entirely free from blemish. We cite this to prove that by the Whitworth process the cavities due to the presence of gas are not diminished in size only, but entirely got rid of. What becomes of the gases, which are apparently hydrogen and nitrogen? It is almost impossible to see how pressure can squeeze

out the gas, and yet be maintained in the mould. But, going a step further, we are presented with a new phase of the problem. It appears to be extremely doubtful that while the steel is fluid any bubbles of gas whatever are found in molten metal. The steel as it runs is quite as fluid as water, if not more so, and the gases, by reason of their levity, ought to rise to the top and escape, and it is quite certain that carbonic acid and carbonic oxide do thus behave. According to one theory, the hydrogen which makes the mischievous bubbles is only given off when the metal is solidifying; but if this be so, as the pressure is no longer diffused through the mass, but produces only direct vertical strains, how can it operate to prevent hollow spaces, which must be closed in from the sides, if at all, as well as from the top? Nor is this all. If Sir Joseph Whitworth states that he cannot get on without pressures of as great as two tons per inch, and even very much more, how is it that good results are obtained with pressures of as little as 80 lbs. and 100 lbs., while it is even assumed, and not without reason, that 300 lbs. of steam may do all Sir Joseph accomplishes? These questions are of very great interest indeed, for it will be seen at once that if solid castings can be made from the Bessemer converter, things will be rendered possible in mechanical engineering which are impossible now. But no such castings can be made at a moderate price, if at all, by the Whitworth system.

Mr. Jones has used steam at the Edgar Thomson works. We illustrated his apparatus last week, and when Mr. Davis' apparatus, now being tried in this country, is perfected we shall illustrate it. But is steam the best thing to use? No decided answer can be given. to this question. Mr. Davis contemplates the use of air; but the cost of a compressing plant will be very much greater than that of a boiler. The great charm of Mr. Jones' system is its cheapness and its simplicity. The moment we depart from the use of steam, and adopt compressed air in its stead, complications and difficulties and expense will be incurred. In pursuit of simplicity, Dr. Siemens, we believe, tried to inject water on the top of the ingot in the mould, beneath, of course, a closed lid, and, if we are not mistaken, Mr. Jones tried the same device. In each case explosions resulted, as might have been expected. But the moment it has been proved that pressure will give solid ingots, no matter how that pressure is applied, various devices may be used to secure the required end. To us by far the most promising scheme seems to be the following: Let each ingot mould be made with a tight-fitting lid which can be readily and quickly put on. Then, as soon as the mould has been filled, let a measured quantity of some gas-producing material be thrown in on the top of the fluid steel and the lid put on. It would be by no means difficult to scheme a safety-valve arrangement, if such a thing were necessary, which it is not. A very few experiments would suffice to determine the quantity of gas-producing material to be used, and its nature. We may suggest one or two. Nitrate of soda and clay made into a cake would give off gas slowly; oil worked up with clay would have the same effect. Even common coal coated with clay by dipping it in a thick "slip," would probably answer the purpose thoroughly. Roughly speaking, coal will give off about 250 times its own volume of gas at atmospheric pressure. At the temperature of molten steel its volume would be probably about 1500 times that of the coal. If there were no leaks in the mould a cubic inch of coal would be ample to give a pressure of some 300 lbs. or so on the square inch. The clay in all cases serves the purpose of keeping the gas-producing material cool for a few seconds until the lid can be put on the mould. The process would be to the last degree simple and inexpensive. It would suffice to throw into each mould, as we have said, a pellet of gas-producing composition, enveloped in clay, and to put on and secure the lid; no costly apparatus of any kind would be needed. The scheme is not patented, and it is open to the whole world to try. It is also worth while to consider whether the adoption of some method of agitating the mould, as by letting it drop vertically and suddenly, though a few inches, just before consolidation begins might not operate powerfully to dis-

engage gas, without any other agency whatever.

Whether the Jones, or the Davis, or the process which we have suggested, be employed, the thing most wanted now is an air-tight lid for the ingot moulds which can be made tight at a moment's notice. The mouth of the mould is protected by a loose plate while the ingot is being filled, and there is a comparatively smooth and clean surface on which the lid can rest, but some kind of packing which will stand a high temperature is essential. Several packings have been proposed; one is a ring of asbestos interposed between the lid and the mould, another is simply a flat coil of copper wire. How the problem may be ultimately solved we cannot say, but we can say that, until it is solved, the Jones system cannot command success. The lids of the moulds used at the Barrow Steel Works, in the experiment made last week, leaked steam so profusely that it is doubtful if there was more than 70 lbs. or 80 lbs. pressure in the mould, although there was 180 lbs. in the boiler. It must not be forgotten that the steam is highly superheated and that while in this condition it will escape readily through orifices which permit but an infinitesimal leakage of saturated steam.

ATLANTIC CABLES.

From "Engineering."

When the first Atlantic cable was laid in 1858, each step in the operations was carefully reported in the daily press, and eagerly perused, owing to the novelty of the work and the intense interest it had aroused in the public mind. In the same way, though perhaps to a less extent, the operations of 1865 and 1866 were made public. In 1869, the cable laid between Brest and St. Pierre, known for some time as the French Atlantic, caused less interest. The cables of 1873 and 1874 were but briefly recorded, and the cables laid last year and this year have scarcely been noticed at all. This is partly due to the rivalry existing between the two telegraph companies, as well as between the firms who have made and laid the cables. Very little information is to be obtained on the subject from the principal persons concerned in the work, who, it would appear, wish to have as little made public as possible for fear of their adversaries gaining some advantage by it. This appears to us excessively childish, for any persons having sufficient interest in gaining particulars of either work, to be willing to incur a small expense and trouble, might easily obtain all the information he desired concerning the cables and operations. The rival parties themselves are not likely therefore to have any difficulty in knowing all that occurs in the enemy's camp, and it is only the public, and those who take an interest in the subject generally from a technical and scientific point of view, who are deprived of the information as to what is being done in this branch of engineering. There may be some slight advantage to contractors in thus keeping all experience and information as much as possible to themselves, but we doubt very much whether this exclusion of all, except those who are actually employed on the work, from any information as to the progress that is being made, is beneficial or will tend towards the advancement of telegraphic engineering generally. Improvements and new ideas do not always come from rich, conservative, and exclusive bodies or corporations, and unless what may be termed outsiders hear a little of what is going on, it is unlikely that they will turn their attention to improvements.

That an improvement on the type of cable employed on the Atlantic in 1865 and 1866, and which is known amongst engineers as "Atlantic type," is required is proved by the fact that these cables had only lives of about 8½ years, and if cables will only last that time, even 10 per cent. dividends will not pay for them, whereas most cables at present only pay about 6 or 7 per cent.

The type we allude to consists in ten homogeneous iron wires, each separately surrounded with strands of Manilla hemp, as the mechanical structure round the jute-covered core. This type of cable, when new, is, of course, excellent

for the process of laying. It has a low specific gravity and great friction from the roughness of the Manilla hemp, and can, consequently, be laid with a given amount of slack with a very small strain during the operation of paying out. But as regards its durability it has little to recommend it. The wires being separated allow insects easily to enter. The hemp rots, and the iron rusts away. The 1873 and 1874 cables had a little hemp and pitch and silica layed on round the whole, and have thus an additional protection, but the coating was meager.

The cable laid by Messrs. Siemens last year we believe consists of homogeneous iron wires touching one another, thus returning to what has been known as the Mediterranean type of cable, the iron being protected from rust by two coatings of yarn, pitch, and silica round the whole cable.

The cable laid this year by the Telegraph Construction Company has ten homogeneous iron wires, each covered with a thick coating of preservative compound called Clifford's compound, the composition of which is kept secret, and these are each separately further covered with tape. Between each wire a strand of hemp is placed. The whole cable thus formed has two layers of tape and pitch compound outside all. The mode of combining hemp and iron alternately round the core has been before largely adopted by the Telegraph Construction Company, and was first, we believe, employed on the cable between Sydney and New Zealand. We do not know what advantages are claimed for this plan, but it would appear to us to be principally a mode of saving first cost, by substituting hemp for iron at the expense of durability. It does not seem possible that the hemp can take any strain properly with the iron, and when the cable gets old, we should think the hemp would not keep the wires in place when the cable is being strained or bent about in repairs, so well as hemp round each wire. It is cheap, and that is all that can be said for it. The strong outer coating of tape and pitch no doubt keeps the wires in place when the cable is new, but we should look to what will be the state of the cable when this outside coating of hemp is gone. When the hemp has perished considerably it seems clear that the wires with wide spaces between them, like a birdcage, will not in the least fulfill the conditions of a wire rope, and we shall be very much astonished if, after a few years of experience at repairing, this type of cable, with alternate wire and hemp, is not abandoned as a mistake. The attempt to preserve each wire with a compound, whatever it may be, is a step in the right direction. Gutta-percha applied in the ordinary way round wires for protection was proposed and patented by Mr. Samuel Statham in 1857. We do not know what Clifford's compound is, but we doubt whether it is better than gutta-percha, though perhaps much cheaper.

As regards the process of paying out there was one novelty in the Siemens expedition which we will describe. It is necessary, in order to distribute the slack of a cable uniformly, or in such places as the engineer may decide on, to know at every half hour the exact position of the ship over the ground. To do this by observations, even in fine weather, is only possible once every twenty-four hours, and when the sky is overcast not even then. Dead reckoning is not to be trusted on account of currents. The following plan was adopted therefore, and forms one of the latest novelties in cable laying: a steel pianoforte wire was paid out throughout all the deep water passage with sufficient tension to insure its being laid without any slack, and thus the distance actually run was measured and known at every minute. The wire was, we believe, in fifty mile lengths on drums, and the lengths were rapidly joined by a hook joint.

In paying out the Anglo-American cable this year two ships were employed, the Scotia and Seine, and when the Scotia had nearly finished paying out her length the cable was made fast to a buoy at some fathoms from the end, the stray quantity being coiled into a lifeboat, and the end thus handed to the bows of the Seine. In laying the Siemens cable last year there was a similar change from the Faraday to the Pouyer-Quertier.

It seems a pity that these operations are not published in detail, as they both no doubt reflect credit on those who have conducted them, and would be of great interest to all who follow up the important question of Atlantic telegraphy.

THE BELGIAN SYSTEM OF SHAFT SINKING.

From "Design and Work."

The process is known as the Kind-Chaudron system of boring large pits, and takes its name from those of the two gentlemen whose combined inventions have produced it. One of them is M. J. Chaudron, a Belgian mining engineer, and the other, Mr. Kind, is a well known German engineer and sinker of artesian wells. M. Chaudron is the originator of the most important feature of the system, which is known as the "tubbing" of the shaft, and Mr. Kind is responsible for the mode of drilling. The sole object of the invention is to avoid the enormous expense which is involved in piercing through strata where water is lodged in such quantity that elaborate pumping machinery is required to keep the boring in a workable state. In England water-bearing strata have not been met with to a serious extent, but in France, Belgium, and other parts of the Continent, it has long been a source of annoyance that rich coalfields could not be reached, owing to the practical impossibility of penetrating with success the water-logged strata. It has frequently happened that years of toil and vast sums of money have been fruitlessly expended in the effort to combat this obstacle. The necessity of some means of eluding the difficulty evoked the scheme of Messrs. Chaudron and Kind, and it has proved in the highest degree successful. The principle upon which their plan is founded is to effect the sinking of the shaft without being compelled to remove the water, and afterwards to dam up the places where the water obtains ingress. The mode of operations will be best understood if shown in connection with the Whitburn Winning.

It is several years since the Whitburn Coal Company undertook the sinking of a shaft close to the sea shore, rather more than half a mile south of Marsden Rock. By the ordinary process they reached a depth of 109 feet, and then they came upon the water-bearing strata. Continuing the work on the old-fashioned style they sank 36 yards further. In doing so, however, the expense involved was enormous. They encountered "gullets" in their progress, from which the influx of water was so great that even a pumping power of 12,000 gallons per minute was incapable of contending against it. Accordingly, the ordinary mode of sinking was abandoned, and the directors determined to make a trial of the Kind-Chaudron scheme. On September 26, 1877, boring on the new style was adopted, and on January 4, 1879, the shaft, so far as the chief difficulty was concerned, was completed. The distance thus sunk by the ordinary process had been 52 yards, 2 inches, and by the Kind-Chaudron process 72 yards, 1 foot, 10 inches. This brought them below the water-bearing strata, and the sides of the shaft having been tubbed, so as to keep back the water, the sinking could proceed in the ordinary manner, which is more expeditious than by the German engineer's method. The total depth of No. 1 shaft now is 241 yards, but the sinking is not yet completed. The first workable seam of coal was met with at a depth of 202 yards, 2 feet, 4 inches. This seam was 8 feet, 9 inches thick, but it was not pure coal right through. A second seam of very good coal, 5 feet 2 inches thick, was met with at a depth of 228 yards, 2 feet, 1½ inches, and a third, 3 feet 1½ inches thick, was found seven yards lower. The seams of which the company are in quest, however, are the Maudlin and Hutton seams, and consequently the deepening of the shaft still continues. In proceeding with the sinking of the No. 2 shaft, the water-bearing strata was encountered at exactly the same depth as in No. 1. Profiting by their previous experience, the company at once brought the improved boring process into requisition. By means of the latter they have now attained a depth of a little over 274 feet, 164 feet 8 inches of which has been bored by the machinery inspected. A depth of 380 feet will have to be reached before sinking operations on the ordinary plan can be resumed.

We now come to the manner in which

the boring is conducted, and the plan pursued at the Whitburn pits is almost exactly similar to that followed in all borings by this process. When the water-bearing strata is reached, the first thing done is to lower a trepan, or drill, which will make a bore-hole of (in the case of Whitburn) 6 feet 7 inches in diameter. This trepan, which weighs eleven tons, is armed with a line of well-shaped teeth or chisels, firmly keyed into the superincumbent mass. Each of these teeth weighs about 3 cwt. The trepan is suspended by thick wooden rods from what is called a *balancier*. The latter is a massive braced timber beam, to one end of which the top of the topmost connecting rod is attached. The *balancier* moves after the fashion of a cradle. By means of steam power, one end of it is pulled down, and the trepan lifted a distance of four or five feet above the bed through which it has to bore. Then the steam cylinder is suddenly exhausted, and the trepan falls with immense force upon the stone, and its strong teeth cut into it at every stroke. Of course the trepan must not be allowed to strike continually into the same place, and a number of men are therefore stationed upon the platform which boards over the mouth of the shaft to give it a turn of an inch or two after every blow. After a certain amount of the stone has by this means been removed, the trepan is hauled out of the shaft, and a large tubular-shaped instrument, called a "spoon," is lowered into its place. It sinks into the loose material, which at once fills it, and the latter is prevented from falling out by two doors, which, as they only open upwards, allow the debris to get in, but, closing as soon as the hoisting begins, hinders it from getting out again. This process is continued until perhaps the total depth to be bored is reached, and then the large trepan is brought into requisition. The last-named, which weighs about 20 tons, works upon the same principle as the smaller one. Its duty is to increase the diameter of the hole from 6 feet 7 inches to 15 feet 5 inches, and it chips its way downwards in the same slow but effective fashion as its predecessor. The debris which it knocks off falls to the bottom of the small bore-hole, but there it is caught by a "cuiller," a tubular iron vessel which holds about 12 tons of the rubbish. The latter is hauled up and emptied as soon as it is filled. The explanation of the mode of boring and the watching of the operation of withdrawing the trepan and the "cuiller" made up almost the whole of the programme. At a quarter-past two the boring process was seen in operation. At half-past two boring ceased, and the work of withdrawing the trepan was begun. An hour was occupied in doing this. The trepan was hanging upon five or six rods, some of which were about 60 feet long, and as the lower extremity of each of them emerged from the shaft, the top of its successor was made fast to the cross beam on the platform before mentioned, and while the trepan with the remaining rods was thus hanging, the rod already out was hoisted away, after which the process was repeated until the trepan itself came up. The rods had to be joined together in the same way in order to get a sufficient length of them to reach the cuiller, and in the hauling out of the latter the method employed in taking up the trepan had to be followed. This procedure occupied, therefore, nearly two hours. It will be seen, consequently, that the progress made is very slow. In No. 1 pit the average rate of advance was with the small bore 2 feet 8 inches per day of twenty-fours, and with the large bore 1 foot 4 inches per day. In No. 2 shaft the average progress so far has been 1 foot 8 inches per diem with the small bore, and 1 foot 6 inches daily with the large bore. Every advance of about ten inches fills the cuiller, and necessitates the protracted process attendant upon its withdrawal and reinsertion. In this mode of working the water in the shaft is not a disadvantage, but an absolute necessity. It softens the rock upon which the trepan works, and allows the debris to be more readily collected and removed. It is, therefore, never interferred with from the time the boring commences until it finishes. As showing the advantage of this method over the extensive pumping system, it may be mentioned that fifteen men are sufficient to conduct the whole of the work connected with the sinking.

This way of piercing through the

moist portion of the earth would have been of no value, however, minus the system of "tubbing" invented by M. Chaudron. When completed, this "tubbing" has the form of an immense metal tube, which is lowered into the shaft and serves as a wall to keep back the water. As it would be impossible to construct above ground a tube over 70 yards long, 12 feet in diameter, the walls of which are from 2 inches to 3 inches thick, and which weighs altogether perhaps more than 1,000 tons, and then place it bodily in the shaft, another plan has to be adopted. This is, first of all, to construct a water-tight bottom, and build upon it the first ring of the tube. Thereupon it is set upon the water in the shaft, and it floats. Sufficient water from that lying in the shaft is put into it to cause it to sink a few feet. Then the next length is added to the tube, and it is sunk down again. Thus the tubbing is gradually built, while it floats all the time in the water, until at last it has attained such length that it rests upon the solid bottom of the shaft. The water is afterwards pumped out of the tubbing, and the false bottom removed. By fixing a bed of moss underneath the edges of the tubbing where it rests upon the bottom of the shaft, the water is hindered from passing underneath. The next thing to be done is to fill up the space between the outside of the tubbing and the walls of the shaft with cement. It will have been observed that the diameter of the shaft bored is 15 feet 5 inches, and as the tubbing will be only about 12 feet in diameter, a space of 3 feet, is left to be filled up. When this is done the shaft is completely water-tight, and then the sinking operations through the hard dry material below the water-bearing strata can be proceeded with expeditiously. This process has been adopted with the most complete success in France, Belgium, and Prussia, and about 40 pits have been sunk with its aid, the cost in all cases being exceedingly small compared with the expenditure incurred under the former system. The first trial of it in England was made at Cannock Chase, in Staffordshire, but there, through some mishap, the tubbing broke, and the work is not yet completed. The No. 1 shaft at Whitburn New Winning is therefore the first in England that has been sunk with success by the process. The invention is as simple as it is unique, and as admirable as it is ingenious, and the study of its details afforded both benefit and enjoyment to the large number of gentlemen who took part in the excursion.

OLD SANITARY LESSONS REVIEWED AND NEW LESSONS CONSIDERED.*

From "The Builder."

Sanitary science may be said to be both old and young. It is so old that we know nothing of its commencement, simply because we know nothing definite of the origin of the human race. The cave inhabitants were skilled in art; but at how distant a period they lived, or in what other respects they were skilled, we have little means of knowing; of this, however, we may be certain, that they would suffer from disease, and would use medicines and enchantments in some form to relieve their suffering.* At whatever period of this earth's history intelligent man appeared, diseases would afflict him; and when remedial measures were invented and applied, then *sanitary science commenced.*

There are problems in natural history which can only be speculative; as, the origin and constitution of matter; the origin of life; the origin of disease. The human intellect is powerless to fathom

* From a paper by Mr. Robert Rawlinson, C.B., read at the Exeter Congress of the Sanitary Institute.

* There are dwellers in caves at this day in parts of Great Britain and Ireland, as, also, in other parts of the world—probably as many as ever in any age occupied such places for residence.

these profound mysteries, and if revelation is rejected, there can be nothing but a blank impenetrable darkness. There is minuteness below the search of the best microscope, and a range in magnitude very far beyond the combining power of the best telescope. One law alone is clear and certain, namely, the universal law of motion, which is change—combination and disintegration—these never cease. That we call life or death pervades the universe; and the life of a system—sun and planets—though extended to millions upon millions of years, is, in the roll of eternity, no more than the life of an emmet, which is born and dies in a summer's day. As old systems perish, new systems replace them, to run their appointed course from birth to maturity, and from maturity to decay. I have neither time nor inclination to attempt to summarise ancient and modern theories as to ultimate atoms, if, or, if not, such exist; as, also, if or not, each atom is sensuous, and that, as a consequence, all bodies have developments of sensuousness in a degree—the combination of atoms in man developing sensuousness in the highest degree; matter combined in living forms other than animal life develops properties very like consciousness, as plants shrink from poisons, and, with apparent avidity, seek wholesome food, in this respect showing an intelligence superior to many forms of animal life. I, individually, should like to believe that plants can think.

But to the purport of this paper: "Old Lessons in Sanitary Science Revived and New Lessons Considered." The most reliable starting point I will take may be found in Leviticus xiv., beginning at the thirty-third verse, where the plague of leprosy is described afflicting the house. Without extracting the whole, the sanitary engineer will recognize "the walls with hollow strakes, greenish or reddish, which, in sight, are lower than the wall." Here is vividly described a tainted subsoil, wet and rotten with saturated filth. The modern remedy would be entire removal of the tainted subsoil, to be replaced by lime concrete, removal of the tainted walls, underpinning with new material, and the introduction of a damp-proof course. Leprosy (or the equivalent of leprosy) affects houses at this day in all parts of the world inhabited by man, from European palaces to the hut of the Esquimaux.* In this malarrangement the savage fares better than the civilized man, as nomad tribes can leave a tainted site, whilst dwellers in villages, towns and cities remain fixed on sites filth-tainted to supersaturation. Seeds of disease ripen in the polluted huts and houses of India, China and Europe, and the North American cities have not escaped this general contamination. Australia and New Zealand have already polluted the sites of their cities to a dangerous extent, so that the mortality returns are no better than those of the old country.

In England we have apparently banished plague, which, however, prevails in the East—Russia, Egypt, and the cities of Asia; but England has ripened the "*germs*" of cholera very recently, and typhus, typhoid, and other forms of fever commonly prevail. That these diseases can be prevented our model prisons bear witness, and modern sanitary works have also materially improved entire town communities. I have used the word "*germ*" as applicable to disease, without in the least being enabled to explain satisfactorily what is meant by it. That types of disease can be introduced and spread will be readily admitted; but that the origin, in each case, is a *germ* is not so easy of proof. It has been suggested that cholera must be conveyed to the human system in water; as, also, that tainted water and tainted milk produce typhus and scarlet fevers; and some say that fluids are necessary to the introduction of those forms of disease into the human system, periods of time being fixed for incubation. There are, however, some facts against this theory being received in its entirety; as for instance, troops and travelers on the march into a virgin country previously unoccupied by man, develop these forms of disease much beyond the assigned period of incubation, and which, under the surrounding conditions, cannot be due to man-tainted earth, air or water; so that the germ theory fails, unless we can imagine that germs of every form of disease which can afflict men or animals

*It may not be strictly proper to use the word "leprosy" as being common to houses; the meaning is, that houses are filth-tainted to an extent which causes rottenness capable of producing disease.

are as eternal as matter, and are dormant in matter until conditions for development are brought about. According to this idea, soil, water and air, and every human body must contain germs of every disease, but dormant, until brought into contact with conditions favorable for development.

The cleanest looking places are not necessarily the safest. A clean looking country house or village, surrounded by pure air free from coal smoke, may have hidden dangers worse than any in a town. Visible dirt is not always the most dangerous, as the rain washes it, the wind blows over it, and the sun dries it. The presence of rats, either in country or in town, is a certain indication of danger, as rats live on garbage. They are usually diseased, and can convey the seeds of disease. It is not possible to predict, in all cases, as to what shall cause disease in excess in any given locality, as filth under peculiar and unknown modifications, or plus an unknown factor, may be sufficient to cause typhoid without the so-called specific germ from a previous case. A telluric influence or an atmospheric influence, which we can neither control nor analyze, in combination with great elemental disturbances, may produce disease in excess. . . .

Past history has, for the most part, consisted of details of the birth, life and death of kings, of their wars and conquests, with a very slight glimpse of the state of the people. In the future, true history will note and record the condition and doings of the people, as constituting the power of the state; but at present the world is very far from this condition. When in this age of general improvement in arts, manufactures and commerce, we find Europe in arms to a greater extent than at any former period, and the people under a load of expenditure the heaviest in the world's history, thoughtful men must pause, wonder and look for some practicable solution. The taxes now being levied and expended on soldiers, armaments, arms and ammunition, would more than serve to abolish every city slum and wretched town tenement, admit of the re-arrangement of every city sewer, and pave every street, drain every house, provide a full supply of pure water at high pressure, and constant service, and pay for daily scavenging. When history can detail these things as accomplished facts, it will be worth reading. Sanitary science is new, but it is not, as yet, popular. To remove filth, to promote health and to prolong life, gain little of a stateman's notice in the battle of politics; the work has, however, commenced and is being taken up, both at home and in our dependencies. The Americans are also becoming earnest sanitarians.

There are poverty, vice and crime in Great Britain which, when contemplated in detail, are quite appalling; and these are the outcome of defective statesmanship—and this after years of political freedom and so-called enlightened government. We sanitarians, however, hold that statesmanship which leaves the largest numerical mass of the population in hopeless misery must be defective. This condition of society is not a sound one; and, consequently, is not a safe one. To see the results of despotism and neglect in their most aggravated forms, we must, however, cast our mental vision over the empires of China and Russia, where millions of men know nothing of political and civil freedom, the results being civil commotions, rebellions and civil slaughter, wholesale arrests, wholesale condemnations, wholesale transportations, and wholesale decapitations, which effect nothing worth the trouble. Because the wretched people have no cessation to their persecution, they exist in misery and have no hope.

True sanitary science recognizes the unit, man—looks at the individual, the single family, the single house, the village, the town and the city, as these constitute nations, and as are the individuals, so must be family, town and nation. If, therefore, there is ignorance, wretchedness and vice amongst the lower orders of the people, the leaven pervades the entire nation.

These questions may be termed political, and it may be said that sanitarians have nothing to do with politics. Our reply, if questioned as to this, must be that to govern men is the prime duty of a statesman. But what are the definitions of the word "govern?" To a despot there is only one definition, and that is, repression; which implies every form of cruelty which man ever devised and practiced. To a British statesman I

hope it means to care for the whole people, to educate and protect them in all honest dealings, to repeal all laws which tend to the commission of crime, to abolish class legislation, and to know nothing of party if it leads to faction.

The domestic side of sanitary science deals with home comforts, and the unit in this case is the house, then the village and the town. Houses must be planned, constructed and regulated to afford means of health and morality to the occupants. Villages and towns must be so arranged, built, sewered, paved and scavenged, as to preserve the purity of the soil below and the air above for the benefit of the inhabitants. To secure such ends there must be sewers, drains, pavements, scavenging, and a water supply. Sewering is ancient beyond written records; sewering scientifically is, however, modern, very modern, as some of those who presided at the birth of the modern system of town sewering are happily now living. Edwin Chadwick, C.B., though not a civil engineer, has, through the aid of engineers, done more to found and promote the true principles of town sewering than any other single individual in this generation.

There were sewers and drains in the cities of Asia which are now heaps of ruins. As in these days, so then, where large areas were covered with buildings, and men were aggregated, there would be sewage; and this would be removed by open channels and covered conduits, necessity having been the mother of invention. These ancient cities were, however, not wholly sewered, but only partially. It is very easy to be positive on this point, namely, that sewers and drains were not general, as there are no remains beneath great areas covered by the common people, and the ruins of which would have been found if sewer and drain pipes had ever been laid.

Rome sewered and drained her cities, public buildings, baths, and palaces from a very early period of her history, and the ruins are there to this day. Pliny describes sewers in some of his letters to the Emperor Trajan. There were not only sewers, but there was also river pollution. The great cloaca sewer of Rome emptied sewage into the Tiber; and Pliny directs the attention of the emperor to a case in a provincial city, where certain banished men resided, apparently living in ease and idleness. There were sewers in the district, and a polluted stream flowed through it, which had become a great nuisance, and was complained of by the inhabitants. Pliny, in this case, suggests that the idle, easy-living, banished men should be more fittingly punished by being made to cleanse the foul sewers, and for the future prevent river pollution. Trajan at once consents to so reasonable a proposition. These letters by Pliny are most interesting, in showing how actively he performed his duties, and how minutely informed he kept the great Emperor.

At Sinope, on the Black Sea, money had been advanced to the municipality for a theatre. A bad site was, however, chosen—a swamp—and the building became a ruin before completion, and the money was wasted. Subsequently, a memorial was sent to Rome petitioning for money to construct waterworks. Pliny, in this case, cautions the emperor, and advises that, if the request is entertained favorably, an engineer be sent with the money, that the local authorities may not job it away, as in the case of the ruined theatre. I suppose the emperor did send an engineer, as, in 1855, I saw the ruins of the service reservoirs, which, but for man's destruction, would have been as entire as on the day of their completion, the walls now remaining being sound and massive as when first constructed.

The making of earthenware vessels by means of the pottter's wheel is of very ancient date; and the work of the potter has, amidst all the ruins of ancient cities, been the most enduring. The vast collection of bricks, tiles, tablets, pipes, and vases placed in European museums testify to this fact At some early period earthenware pipes were thrown on the potter's wheel, having sockets for jointing similar to those now made in England. I saw samples in Asia Minor, in 1855, evidently new. They were about 13 inches in length and 5 inches internal diameter, having a socket of about 1½ inches in depth. They were being laid at Kulali, situate on the Bosphorus, to form a conduit to bring water to the barrack hospital. The natives were at work laying the pipes on a contour line, a considerable length of trench being open.

I did not at first see any arrangements for ventilation and wash-outs, and was questioning the engineer officer upon these points, as to whether or not they had been provided for, and making a rough diagram, scratching on the ground with a stick to illustrate my questions. The engineer officer could give no information; but one of the native workmen, who had been listening to and watching us, touched me on the shoulder, and, with a sparkling countenance, said, "*bono-bono*," immediately taking me along the line of aqueduct, and pointed out the structural means I inquired about, both for ventilation and for wash-out.

Aqueduct making is a very old Eastern practice; aqueducts, fountains and wells being common all over the inhabited parts of Asia. Water, as one of the elements necessary to life, was, in a warm climate, sought for and stored carefully. A very meager history of springs and wells would form a large book, and might be as interesting as the most vivid romance. There are holy wells throughout Asia, and there are also holy wells and fairy wells in Europe, novelists having with great effect availed themselves of these superstitions, and woven them into their descriptions of supernatural phenomena. There is, in fact, an enormous amount of superstition, romance and poetry connected with springs. Magical virtues are attributed to many waters, a belief in which leads to incalculable injury.

There are shrines in India within which are reputedly sacred waters, to be washed with, and to be drunk by the pilgrims to secure eternal salvation. On certain days in the year thousands of the natives assemble and encamp round these sacred shrines. The approach to the holy water is by a flight of marble steps, down which perspiring natives, many of whom are crippled and diseased, throng to have a cupful of the fluid. The practice is to pour a cupful over the head of each native, to flow back to the tank, and this hundreds of times repeated during the day, so that it ceases to be water and becomes a vile compound—the washings from the bodies and feet of natives—and this horrible decoction the priests in attendance administer to be drunk by the poor besotted votaries. Cholera usually breaks out amongst the pilgrims at these gatherings, and it would be contrary to the known laws of sanitary science if it did not do so.

Recently there has very properly been a rage for water analyses, many thousands having been made in Great Britain and in British India, and very startling conditions have been revealed. Water which has been considered pure by the inhabitants of English towns has been found to contain a dangerous proportion of polluting matter, to the effects of which they appear to be stupidly apathetic; but the researches in India reveal a state of things almost too terrible to comtemplate. The natives of India are expert diggers of wells and formers of tanks to supply and store water for use; they are also careless of life, committing suicide with apparent avidity, death by drowning being common. It had been observed that at certain Indian stations British soldiers were liable to be afflicted with virulent types of disease—as cholera, fevers, and, at Delhi, carbuncles and sores, the Delhi sores having become a recognized affliction. Inspection was ordered, when it was found that within the province there had been about 1700 carcasses of human beings removed from tanks and wells, the water from which had been regularly used for human consumption. Some of the worst wells were ordered to be cleansed, when many human bones were removed from them. The tanks in use are open, and the surrounding ground slopes towards the water; over the surface human excrement is spread, and the natives both wash clothes and bathe in the water they use for cooking and drinking. High caste apparently affords no protection, but acts in a contrary direction. Calcutta is supplied with filtered water, but high-caste natives decline to use it. A native water-carrier was observed filling his skin at a stand-pipe with filtered water, but when about three parts filled, he went to the nearest puddle, and with his hands proceeded to fill his vessel. An Englishman, observing him, asked what he was doing, when he replied, "Making Ganges water for master."*

* Great improvements have been made at stations throughout British India in improving and in guiding water-supply sources, both tanks and wells, to prevent pollution; these improvement works are now going on.

Some medical men state that pure water is absolutely necessary to health; others send their patients to drink the most abominable compounds at English and foreign spas. Pure water is a rarity in nature, and where it is found it must be protected with great care, as it is a powerful solvent and greedy of impurities. The solvent property of rain-water, which is the nearest approach in nature to pure water, is probably amongst all the elements the most powerful agent in moulding and disintegrating the solid earth. By way of illustration, the river Thames may be taken. The water of this river contains, in round numbers, about one ton of bicarbonate of lime in each million of gallons, when the water is clear, bright, and sparkingly transparent. The daily supply pumped into London is now about 135,000,000 of gallons, so that 135 tons of bicarbonate of lime is combined with the supply of each day's water, or upwards of 49,000 tons per annum. The average flow of water down the Thames may be taken as 1,000,000,000 gallons per day; so that about 365,000 tons of bicarbonate of lime is washed down per annum from the Thames alone. About four-fifths of the dry land of the earth contain lime, or are limestone, upon which this dissolving action of rain water is unceasing; so that the whole of the solid earth above sea level may be silently washed and wasted down into the great salt ocean. Soft water being so powerful a solvent, is economical for washing, but it is vapid for drinking, and it is liable to produce diarrhœa when peat-tainted. It has not been proven that hard water (hard as Thames water) is injurious to health; it has, however, been demonstrated that it is a great protection to health when it has to be brought into contact with metals—lead, zinc, and some other substances. It is the duty of the sanitarian to obtain clean water, and to preserve it fresh, cool, and clean; but pure water—in the full sense of the word "pure,"—I do not believe to be necessary to health—as spring, stream, river, and well waters necessarily contain salts of the rocks they come into contact with, and these are the waters which are the most largely obtained in nature, and in by far the most cases can alone be obtained, and must, therefore, be accepted. Contaminated water must be dangerous, and should always be avoided. Contamination is not, however, the most dangerous when the water is most visibly polluted. The turbid waters of the Nile, in Egypt, and of the Ganges, in India, are taken for use in preference to all other water. These mighty rivers are, however, usually turbid, the suspended silt acting as a disinfectant.

The filthiest and most dangerous water to drink is well water, human-excreta tainted, which water may be clear and sparkling. Surface water flowing down brooks and rivers, though visibly polluted, does not appear to be as injurious as tainted well-water, earth and air being purifiers of surface water. Water, when inclosed and stagnant, as in wells, pipes, or small unventilated tanks, and especially when affected by liquid or gaseous impurities, becomes stinking and unwholesome. In water works the water to be impounded in reservoirs should be gathered from the cleanest possible sources, and should be preserved clean. Sand filters should be close to the service reservoirs, which should be covered and fully ventilated. The supply from the reservoir and the supply mains should be direct, and the mains should be so laid and connected as to produce continuous circulation, as water retained a long time dormant in "dead ends" rapidly becomes deteriorated. The best water supply will be one which secures the purest source, and by the works of storage and distribution preserves it the purest up to its delivery for use.

Bathing and washing are necessary to health, but there are many towns in Great Britain and Ireland without adequate means for bathing and washing; and, as a consequence, the people do not bathe and are not clean. Baths are common in better-class houses, though by no means as common as they should be. The "tub" is, however, used as a substitute. The poor cannot provide their own baths. These ought, therefore, to be provided for them by the municipal authorities in the best and cheapest form, and in the most convenient positions. With the baths should be wash-houses, where water, soap, and all the apparatus necessary for clean and rapid washing, drying, mangling, and ironing

should be made available at the least practicable cost, and if sites are judiciously selected, and there is no extravagance in the construction and management, there need be no loss. But a small rate in aid, if required, will be a saving indirectly in promoting cleanliness, sobriety, and improved health.

A writer I have before quoted remarks that in Japan bath-houses exist in great numbers in the towns, where warm water is provided at a small cost. These baths are for the benefit of the poorer classes, who use them in great numbers; as regularly as evening comes crowds of Japanese men and women go to bathe. There are ranges of box-shelves where the clothes are placed, whilst the individual steps into the bath, emerges from it, well rubs the skin, dresses, and departs clean in person. In Great Britain, at this day, thousands upon thousands of the poor are never washed clean from their birth to their death, unless they go to prison or to the workhouse. There is no bathing accommodation provided. At all schools there should be baths, and complete washing should be a part of education, as those who are accustomed to regular personal washing in youth will not subsequently abandon it.

Sanitary science has, during the last half century, probably made most progress in England; but then this island is a very small spot on the globe; and even England—free, rich, compact, and educated as it is—only progresses slowly. It may, however, be interesting to this meeting to learn that there is an Association of Municipal and Sanitary Engineers and Surveyors to the number of 205, and that 197 towns and districts are represented by the members. The extent of work executed might be indicated by the make of earthen ware pipes and other sanitary articles, if a reliable return could be obtained. The Messrs. Doulton are making about 1,300 miles of drain-pipes per annum, besides many thousand soil-pans; and this may be about one-tenth of the entire English make of sanitary articles. There is not time in a public address to deliver a closely-reasoned essay, and a popular address is not, I assume, expected to be other than discursive. The following remarks may interest the public, though they may not teach much to the educated engineer:

SEWERS AND DRAINS.

There are good and bad sewers and drains, and the public should know some of the reasons why this is so, and then they may refrain from condemning sanitary works in general. Sewers and drains have been formed which are so defective as to be a cause of serious nuisance; they are too large, have wide and flat bottoms, the materials are bad, and the construction worse. It is possible to damage a town by defective works, and so bring discredit on sanitary science. I will attempt to describe how a town ought to be sewered, and how houses ought to be drained, to fully answer the purposes intended. Correct plans and sections are required upon which to lay out the system of sewers and drains to be constructed; the depths of the cellars should be figured on the sites of houses; the relative levels of the streets may be indicated by contours, and on the sections the strata should be shown by colors. A careful engineer will test the strata by boring and trial holes. Full details how to lay out sewers in right lines, both on plan and in gradient, are given in the "Suggestions" published by the Local Government Board.

An engineer should settle at the commencement what duties the sewers will have to fulfill. If the town has manufactories consuming and polluting much water, the question may arise, if or not this polluted water is to be removed by the town sewers; there will also, in some cases, be a question of injurious fluids, such as tan-pit refuse and pickle-waste from brass founders, lacquer manufacturers, and tin-plate workers; there are also dye waters and soap-waste from woolen manufactories—some of these fluids can be treated on the premises to precipitate the solids and disinfect and clarify the fluids, and, consequently, where there is no land available for sewage filtration, the manufacturers may reasonably be called upon to clarify their polluted liquids—and not pass them in their crude state to the sewers. There are wet and dry subsoils. Sewage will, upon good gradients, flow to any point required by gravity; in other cases there

may be a flat area with a wet subsoil, and a swamp for an outlet, or this may be below the river or sea level. In such cases pumping may have to be resorted to, and then it is desirable to reduce sewage to a minimum. The subsoil should have independent drainage, and the sewers and drains should be water-tight, surface water, including rainfall, being otherwise provided for.

To construct water-tight sewers and drains requires the best materials and the most careful workmanship, but these, indeed, are necessary under all conditions. In a wet subsoil land-water should be excluded; in a dry subsoil, the sewage should be prevented from leaking out of the sewers. In the foregoing remarks extreme cases of wet and dry are contemplated. If sewage has to be pumped and has to be clarified by irrigation, the volume to be dealt with should as near as practicable be a constant quantity. If, however, there is a free outlet by gravity, the sewers may be allowed to partially receive both subsoil and surface water; only, however, to some known and limited extent. It is an advantage to have a wet sewer rather than a dry one. Sewage flows intermittently during portions of each day, when the inhabitants are using most water; if there is no subsoil water, the sewers at intervals may be comparatively dry, admitting of deposit. A steady continuous flow of water through sewers sufficient to maintain a regular current, and not more than a few inches in depth in the main sewers, will be an advantage. Main sewers should ordinarily be laid at a depth sufficient to admit of the deepest cellar being effectively drained, the invert of the branch drain being at the least 1 foot below the cellar floor, the fall of the house drain being not less than one in sixty, and entering the main sewers not lower than half its diameter. These remarks are of course general, and cannot in all cases be acted upon, as many towns have low sites which cannot be effectively sewered and drained without special means (air-valves) to prevent cellars being flooded by back water from the sewers, or by special pumping. House drains, as a rule, should be outside the basement of the houses. But where houses are built in streets, and the kitchens are at the back, the drain must cross the basement unless back drainage is adopted, when no drain need enter the basement. Much has been written and said both in favor of back drainage and against it. I have had twenty years' experience of back drainage, and know nothing but good of it. It has been said that it is an interference with the rights of private property; that the drains will choke, and then there must be trespass to find out the point of failure. My reply is that back drains may be so laid that nothing but gross usage, amounting to willful action, can choke them; and even in such a case they will be freed and cleansed without trespass, as manholes and flushing will enable them to be so cleansed. To enable sound sewers and drains to be constructed, the trenching must be true, and the bottom to receive sewer or drain must be absolutely sound and solid. There must be no mistake here, or the work will soon be a nuisance and a ruin. Sewers and drains may become broken-backed; then there will be leaking joints or saturated subsoil, and a choked sewer or drain will bring discredit upon sewering. If the bottom of a sewer or drain-trench is not sound, it may be made so by cement concrete, and in loose wet quicksandy ground sewers and drains should be covered with concrete. Sewers and drains will work better, and be maintained in better order, if subjected to regular and properly-graduated flushing at short intervals. It is possible to overflush, and so injure the sewers. As much water as will give a velocity of about 6 ft. per second may be admitted; greater force, to give a quicker velocity, will be liable to injure brickwork, and blow or force open pipe joints.

Waterclosets and sinks should be against outer walls; should not have continuous flue-like connections with the sewers, but have a severed connection, and means for full external ventilation. Every public building, however large, and every house, however small, should be so drained as to afford no possibility of sewage gases entering, and they should stand absolutely free from the sewers, though perfectly connected with them; this might be a law without any exception. At present almost every public building and house in London is in direct communication by the drains, with

the sewers, so that sewerage gases pervade them; there are open sewer ventilators in the streets, which serve to dilute the sewage gases, and the enormous number of houses perform a similar purpose, and it is this dilution which prevents the full amount of mischief from being experienced; but there is a danger in it, and this ought to be avoided. This is to be done by absolute isolation and external ventilation above the roofs of the houses. In Leeds, for a population of 320,000, there are upwards of 20,000 openings from the sewers acting as ventilators, which have been in use more than seven years. This is an example other towns may follow with advantage. Perfect sewering requires perfect street paving and perfect street cleansing. Scavenging must, in all cases, be a work of the municipality, or other local governing body. Contract work should be avoided. The work of scavenging should be paid by rate, and this rate should be general.

Waterworks should, in all cases, be in the hands of the local governing body. The service should be constant and at high pressure, with fire service provided for. Water should be laid on to every house and to every tenement; there should be no exception. The service pipes may be of wrought iron, with screw joints, and all the taps should be "screw-down." If the services are taken within the houses and tenements, and the service is high pressure and constant, there will not be much willful wasting of water, and house taps will not be stolen, as waste of water, when at high pressure, will be very disagreeable within a house. Fix stand-pipes in streets and roads, as is done now, and the waste will continue to be unceasing, because it will not inconvenience any one, as when it is within doors. The poor cannot have a full and fair use of water if it is alone obtainable from external stand pipes, as this involves carrying and storing within the tenement. It should also be remembered that one gallon of water weighs 10 lbs., and that fifty gallons weigh 500 lbs., and this will only be ten gallons per head for a family of five persons. The labor required to carry 500 lbs. of water each day, or eighty tons per annum, will simply be enormous, and ought not to be expected from the poor tenant. Serve the water within the house, have necessary supervision, and take charge of repairs; the inhabitants will then be properly supplied with water, and cannot easily waste it. Before closing these brief and imperfect remarks I may glance at a few works recently executed, or which are now in progress.

Calcutta has been partially sewered, Bombay is now in course of being sewered, and preparations are in progress for sewering and draining other Indian cities. Sewerage works at Berlin are also in progress, to be completed with sewage irrigation. Dantzig has been completed, with sewage irrigation added; and main sewerage plans are being prepared for other Continental cities. At Warsaw, with a population of 350,000, the estimate for sewers is £600,000. Buda Pesth, population 270,000, main sewering under consideration. St. Petersburg, population 670,000, estimate for sewers £3,000,000, to include pumping and sewage purification. Munich, population 250,000, estimate for sewering, £600,000. Dusseldorf is to be sewered by Messrs. Lindley, of Frankfort. Messrs. Lindley have sewered Frankfort-on-the-Maine, population 125,000, cost £380,000. Out of 6,800 houses, 5,200 have been completely drained, and in the town there are about 22,000 water closets. At present the sewage goes into the river Maine, but it is to be intercepted and clarified. The Prussian Government insists on sewage clarification, which, at present, is stopping sewering on the Rhine cities, where it is very much needed. The water of the Rhine is, however, used for domestic purposes by the population on its banks, and it ought, therefore, to be preserved free from sewage.

French and Belgian towns remain with cess pools; even Paris and Brussels, with their enormous and costly main intercepting sewers, are cities of cesspools, and I do not know of a single well-drained city in Italy. We are met here in this ancient city of Exeter to discuss sanitary science and preventive medicine, engineering and sanitary construction, meteorology and geology—to give information and to receive information on subjects which we consider to be of vital importance to each individnal man, to each town and to each nation; but when

we read the current newspaper literature of the day, we seem as men beating the air. Statesmen pay very little attention to our subjects, but starve labor by conscription, impoverish populations by taxation, and, at enormous cost, provide the most refined and terrible weapons for human destruction. We are in the midst of a war *furore*, and sanitary works can have no solid and satisfactory progress under existing conditions. There is over the length and breadth of Europe a rampant military spirit; armies, armaments, ironclads, and 100-ton guns, attract most attention. The people are summoned from far to witness autumn manœuvres conducted by emperors, as if soldiers were the beginning and ending of human progress and civilization. The Americans appear to be the only sane nation. The governments of the Old World are drunk with military ambition.

EDISON'S ELECTRIC RAILWAY ECONOMICALLY CONSIDERED.

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Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE principles essential to the successful use of electricity as a means of transferring energy, and its economical conversion into work, were conceived by Mr. Edison long before his labors upon the telephone and electric lamp gave him time to verify his theories practically; and although these principles apply to all machines which convert electrical energy into work, it first assumed practical shape in the development of an electric railway system, including not only the locomotive but a complete system of signals, brakes, and switches, operated by electricity. The advantages resulting from the use of electricity in operating railroads are numerous. Economy is of prime importance. The older form of Mr. Edison's dynamo-electric machine will convert ninety and seven-tenths per cent. of the power developed into electrical energy,* the remainder being lost in friction of belts and shafting, and an inappreciable amount in local currents.

In the improved form of dynamo the loss from friction will be considerably reduced, the engine being connected direct to the armature shaft, and both engine and dynamo secured to one rigid cast-iron sole-plate.

The dynamo as constructed for railroad purposes will be capable of converting one hundred and twenty horse power into electrical energy without heating the machine appreciably, the internal resistance being only one-thirtieth of the total. The available energy is therefore twenty-nine times that lost in the machine.

It is well known that a motor can be driven under such conditions that ninety per cent. of the electrical energy required to drive it will be returned in work, and upon a railway, under varying conditions of speed, eighty per cent. will represent a fair average.

If the effective conversion of the dynamo be assumed as ninety per cent., twenty-nine thirtieths or eighty-seven per cent. is available on the line, and eighty per cent. of this, or sixty-nine and six-tenths per cent. of the energy expended is returned in work by the electric locomotive.

Let it also be assumed that, during wet and foggy weather, the leakage from the conducting rails reduces the efficiency to fifty per cent. or half the original amount. Assuming that the Porter-Allen high-speed engine will develop one indicated horse power for two and one-half pounds of coal, five pounds will be required for a horse power developed in the electric locomotive, when the road is in bad condition and locomotive working to disadvantage.

Careful tests of the best type of steam locomotive give an average of six pounds of coal per indicated horse power,* when special skill and attention are called into

* "Scientific American," May 15, 1880. Tests made by Profs. Brackett and Young, of Princeton College.

* "Engineering," Vol. 29, Nos. 756-757. Tests of a Baldwin locomotive.

requisition for firing and running the engine. Under these circumstances, comparing the unfavorable conditions for electric locomotives with the most favorable for steam we have five-sixths the consumption of coal.

The steam locomotive consumes sixteen per cent. of the power developed in overcoming friction in the complicated working parts, whereas the electric locomotive, with its few working parts and simplicity of arrangement, will consume, at the most, but six per cent., a gain of ten per cent. over the steam locomotive.

The ratio of coal consumed per effective horse power applied to draw the load will be as five and thirty-hundredths pounds to seven and fourteen-hundredths pounds, or twenty-five and one-half per cent. in favor of the electric locomotive. It is well known that the amount of unconsumed coal thrown from the stack by the blast in anthracite burning locomotives, drawing fast passenger or heavy freight trains, is often twenty per cent. of the entire amount, and in bituminous burning locomotives is never less than five per cent. in unconsumed hydro carbons and cinders. It is also stated on good authority* that, from improper attention to the firing and running, the amount of fuel is usually increased from twenty-five to fifty per cent. above what is necessary with proper care. Assuming as a fair average twenty-five per cent., including in this all contingencies, the coal per effective horse power in the two cases will be in the ratio of five and thirty-two hundredths pounds to eight and ninety-three hundredths pounds, or forty and four-tenths per cent. in favor of the electric locomotive.

The high and mean economy of the steam locomotive have been compared with the least economical duty of the electric locomotive. A comparison with the most uneconomical performance of the steam locomotive is not necessary, but the ratio of the mean economy of both will present them in a fair light.

It has been stated that the older form of dynamos show an efficiency of ninety and seven-tenths per cent.

Taking advantage of the experience gained in their construction, by the tests subsequently made upon them, and embodying the results of numerous experiments in the construction of the one hundred and twenty horse-power dynamo, Mr. Edison is confident that the efficiency will be increased to the extent that ninety-five per cent. of the power developed will be converted into electrical energy, and twenty-nine thirtieths, or ninety-one and eight-tenths per cent. will be available. Of this we will assume the average loss from leakage to be ten per cent., which leaves eighty-two and six-tenths available on the line. Assume, as before, that eighty per cent. of this is returned in work by the motor, or sixty-six and one-tenth per cent. of the original power. At two and one-half pounds of coal per horse power at station, the consumption per horse power returned by locomotive will be three and eight-tenths pounds, or four pounds with six per cent. lost in friction of motor.

The ratio of mean economy for both is therefore four pounds to eight and ninety-three hundredths pounds, or fifty-five and two-tenths per cent. in favor of the electric locomotive.

The foregoing comparisons apply to stationary motors as well as to locomotives, excepting that in the first the economy is constant, but in the second it changes slightly, owing to the variation in resistance as the locomotive passes over the line. When Mr. Edison first made public his opinions and purposes, they did not awaken engineers to serious thought, but, on the contrary, it was to them a pleasant diversion, and they were inclined to look upon it as an eccentricity of genius, not in any way adapted to practical use. While not assuming to know what power could be returned by the locomotive, they did say that since engines must be used, why not use them where they are wanted to do the work—upon the line?

Mr. Edison fully understood the facts as they were—not as supposed to be—before announcing his views to the engineering public, and close attention to the facts will show that he is correct as to the practicability and economy of a railway system operated by electricity. As to the consumption of coal per effective horse power, the comparison has been already made. The economy in fuel is obtained by substituting the mos

* Vose's Manual for Railroad Engineers, Chap. XVII.

approved form of boilers and economical type of stationary engines for the present locomotive, in which imperative practical considerations prevent any approach to the economy attained by the stationary type. The saving by this method is so great that, after the efficiency has been reduced by loss from conversion into electrical energy, leakage upon the line, and loss from reconversion and in friction of working parts, the economy is still twice that of the steam locomotive.

The stations where the electricity is produced, if located ten miles apart, could be built and and equipped, according to present estimates, at much less cost than the equipment in the present system. The depreciation of the plant and locomotive would not be one-fourth of the present depreciation, as stationary engines are used and skilled attendance is employed; also the mechanism of the electric locomotive is very simple, and has few moving and no reciprocating parts to keep in proper alignment, therefore none of those irregularities of motion, which subject the present locomotive to continual shocks and sudden strains, and which are the cause of rapid depreciation.

The engine requires but one man of ordinary intelligence for driving and attendance, while at the station ability of a higher order is employed, so that, by judicious management, economy of fuel is attained, and proper care of plant ensured. From this central source of power is obtained the agent by which all the switches and signals are made automatic, or they can be worked by an employee from a central point on the section. The signals at night are lighted and extinguished by the same, which also furnished power to the brakes, and another circuit from the rails gives out light in the cars. For railroads with heavy traffic and worked up to their capacity, estimates have been made which, if approximately correct, show that the cost of operating would be reduced certainly one-third, and upon narrow gauge roads, for thinly-settled and mountainous districts, the first cost of equipment, as well as economy in operating, is much in favor of this system. In mining regions, where ores have to be transported to a distance and over heavy grades, the locomotive is not limited in hauling capacity to traction, but by a mechanical device the locomotive obtains a firm hold upon the rails, and all the power can be directly exerted in drawing the locomotive and cars attached.

When upon a level part of the line, the gripping device is detached and traction alone is relied upon, and the train moves at a higher rate of speed.

The power required in each case would be nearly constant, but speed would be less upon grades. On large plantations, where the tram cars are drawn by mules, and locomotives are inadmissable on account of sparks, the electric locomotive would be invaluable, and upon elevated and surface railroads in cities, in tunnels, and in mines, where the atmosphere is contaminated with suffocating and poisonous vapors from the steam locomotive, it will be a blessing welcomed by all mankind.

REPORTS OF ENGINEERING SOCIETIES.

At the twenty-eighth annual meeting of the American Society of Civil Engineers, held November 3, 1880, the following officers were elected for the ensuing year: President—James B. Francis; Vice-Presidents—Ashbel Welch, Octave Chanute; Secretary and Librarian—John Bogart; Treasurer—J. James R. Croes; Directors—C. Vandervoort Smith, D. J. Whittemore, Joseph P. Davis, G. Bouscaren, William H. Paine.

American Mechanical Engineers.—The first annual meeting of the American Society of Mechanical Engineers began in this city November 4. About sixty members were present. Prof. R. H. Thurston, of Stevens Institute, presided. The secretary reported an enrollment of two life members, one hundred and sixty-one active members, seventeen associates, and nine juniors. The president submitted the following list of papers to be read before the society:

"Friction as a Factor in Motive Power Expenses," Prof. John E. Sweet; "An Adaptation of Bessemer Plant to the Basic Process," Prof. Holly; "Measurement of the Friction of Lubricating Oils," C. J. H. Woodbury; "Strength in Machine Tools," Charles T. Porter; "The Efficiency of the Crank" and "Adjustment of Cushion in Engines," S. W. Robinson; "A New Type of Regenerative Metallurgical Furnace," Prof. Reese; "Standard Screw Threads," George R. Stetson; "On Practical Methods for Greater Economy of Fuel in the Steam Engine," Allan Stirling; "Putting a New Crank pin in the Crank of the Steamship Knickerbocker," Lewis Johnson; "Mechanical Correctness," Charles A. Hague;

"Packing for Piston-rods and Valve-stems," Prof. Lyne; "Study of the Mechanical Theory of Heat," Prof. Wolff; "The Metric System—Is it Wise to Introduce it into Our Machine Shops?" Coleman Sellers.

ENGINEERING STRUCTURES.

The Orenburg Bridge over the Volga.—The new bridge which has been built for the Orenburg Railway over the Volga at a distance of 17 versts from Syzran, in the Saratov Government, is completed. The great bridge at Sloerdyk, over the Hollandsch Diep, is shorter than this Volga bridge by six meters. The length of this new bridge is stated to be 696 saschenes, or 1485 meters=1623.986 yards. Its building was commenced on August 17, 1877, so that it has taken just three years to finish. The cost has been 4,630,000 roubles, or nearly £694,500. Four hundred thousand pounds of iron, or 6,552,400 kilogrammes=5149 tons very nearly, have been employed in the construction. The bridge rests on 13 arches, and the plans were prepared by Professor Beleloubsky, of St. Petersburg. The Russian papers boast that neither England, France, Germany, nor even America, have built such long bridges as their own country, but the Victoria Bridge over the St. Lawrence is the longest. After this new Volga bridge and the Dutch bridge, at Moerdyk, over the Hollandsch Diep, already mentioned, the next longest bridges are, says the *Times*, the Dnieper, at Kiev and Krementschok respectively, in the government of Pultova, the former of which is 1081.68 meters (=about 1182 yards), and the latter 975 meters (=1065 yards 2¼ feet) long. Then comes the bridge over the Waal, at Bommel, in the Dutch province of Gelderland, 917.4 meters (=1002 yards 2 feet) in length. Next in length is the great Mississippi bridge, connecting East St. Louis with St. Louis, which was built between 1869 and 1874, and cost ten millions of dollars, or almost three times as much as the new Russian bridge; it is 772.32 meters—884 yards—long, and rests on only three arches, the middle one having a span of 158 meters. The bridge near the mouth of the Vistula, at Dirschau, in East Prussia, follows, and the Dutch railway bridge over the Lek, at Kuilenburg, on the line between Utrecht and Boxtel, which are 706.19 meters (=761 yards 2½ feet) long. Next comes the Britannia tubular bridge, which is more remarkable for its admirable construction than its length of 556.84 meters (=almost 608 yards 2 feet). The bridge between Praga and Warsaw, 507.77 meters (=555 yards) long, comes next; and then the fine Alexander bridge, only finished last year, between the Finland bank of the Neva and St. Petersburg, which is 405.36 meters (=447 yards) long, considerably less than a third of the length of the new Volga bridge.—*Engineer.*

London Bridges.—Sir Joseph Bazalgette is one of the most fortunate of English engineers, for after exhibiting his powers in designing and carrying out the vast main drainage system of the metropolis, and the several miles length of Thames Embankment, he has now the privilege of reconstructing some of the principal Thames bridges. At present he is strengthening the Chelsea Suspension Bridge by the addition of a third chain on either side, Messrs. Appleby Brothers, of Greenwich, being the contractors. He will also shortly proceed with securing the foundations of Waterloo Bridge at a cost of £40,000, and enlarging the central opening of Vauxhall Bridge by throwing three arches into one. The most important portion of Sir Joseph's bridge-work will, however, be the reconstruction of Putney and Battersea Bridges at an estimated cost of about half a million. Parliamentary powers for these works will be sought next session.

The Tay Bridge.—The bill for the reconstruction of the Tay Bridge has been thrown out by the Select Committee, so that the matter will now have to stand over until next session. According to the plan of reconstruction laid before the Committee, a plan for which Mr. Brunlees was the engineer, the clear height beneath the large spans would be reduced to 77 feet, and the spans would be carried on brick piers founded partly on the existing caissons and partly on supplementary caissons to be sunk by the side of those now in place. The existing piers of the small spans were also to be strengthened. Mr. John Cochrane, who gave evidence in favor of the scheme, stated that if the proposed plans were carried out the bridge could be rebuilt in two years, while if it had to be entirely reconstructed four years would be required. The Committee, however, did not feel justified in sanctioning the mode of reconstruction proposed, although they agreed that it was desirable that the bridge should be rebuilt, and that the present site was the most suitable.

The Harlem Bridge.—Together with its approaches, the new Harlem bridge will begin where Madison avenue now ends, and reach to One Hundred and Thirty-eighth street, Morrisania. It will consist of two fixed spans at each end, each of 73 feet, and a draw span of two openings, each to be 150 feet long. This will make the entire bridge about 600 feet in length. There will be five stone piers and two abutments. The center pier is now completed. It is 47 feet in diameter at the base and 36 feet at the top. The second pier on the east side of the river is well under way. The side piers will be 16½ feet wide at the base, 5 feet wide at the top, and 40 feet high. The estimated cost of the piers is $70,000. The superstructure of the bridge will be a plain truss of iron. Its design has not yet been fully determined upon. The height above high water of the middle span will be 28 feet, while that of the fixed spans will be 25 feet. The cost of the superstructure and approaches will be about $130,000. The roadway of the bridge will be 22 feet wide in the clear, and there will be sidewalks on each side 5 feet wide. In Morrisania, Madison avenue will be graded to the slope of the bridge from One Hundred and

Thirty-seventh street. One Hundred and Thirty-eighth street and River avenue will pass under the approach. The masonry will be completed by January 1, and lt is expected that the approaches and superstructure will be finished by July 1 of next year. The foundations of each pier are made by driving piles into the bed of the river and cutting them off at a level of 28 feet below high water mark. Upon these is built masonry of cut granite about 40 feet high. The piers are built in wooden caissons, and on these are floated over the piles and sunk with great accuracy. The piles are driven by a hammer weighing 3,000 pounds, which falls 8 feet, and moves the piles not to exceed one-twentieth of a foot at the last ten blows. The piles are so driven into the river bed that they will sustain 20 tons each. The river bed here is of sand and gravel. Mr. McAlpine is the engineer of construction, and the contractor is John Beattie. The amount already paid out upon the work is $40,000—*Iron Age.*

DIFFERENTIAL TRAMWAY AT THE STONE QUARRIES OF LAUFEN, SWITZERLAND. There are two workings at Laufen quarries, of which the eastern one is without difficulty connected with the main line of the Basle-Delle railway; but in the case of the western quarry, where the beds lie at a lower level, on the bank of the River Birs, special means had to be adopted for transporting the stone, the available area for sidings being very limited.

A substantial timber bridge, crossing the River Birs near this place, already existed, from which, leading to the quarry, was a natural incline of about 1 in 17, allowing a tramway to be laid of the same gauge (4 feet 8½ inches) as the main line, with an additional central rack rail, into which was geared a toothed wheel and winch, worked by four men from the platform of a four-wheeled lorry, the ascent of the incline (148 feet long) being accomplished in about fifteen minutes (load not stated).

This arangement answered the requirements satisfactorily until, with an increased demand for the stone, it was found insufficient for the work. Since the spring of 1878 a miniature locomotive, made by M. Riggenbach (the engineer of the Rigi railway) at his works at Aarau, has been employed, and the permanent way of the incline modified as follows:

In addition to the 4 feet 8½ inches track, an inner road of about 2 feet 9 inches gauge has been laid down, the rails of which are slightly higher than the outer ones. The axles of the locomotive are furnished with additional sets of wheels corresponding to the inner track, and a toothed wheel on the driving axle gears with the central rack by which the engine ascends the incline. At the head and foot of the gradient, the inner track and rack rail are gradually depressed, whereby the ordinary driving wheels are lowered to their bearing upon the 4 feet 8½ inches guage, and the transfer from the ordinary track to the inner railway and rack rail, and *vice versa*, is effected without diminishing speed.

The principal dimensions of the engine are:

	Feet.	Inch.
Diameter of cylinder	0	9½
Stroke	0	12½
Diameter of outer driving wheel	0	19½
" inner running "	0	16¾
" toothed wheel	0	17
Pitch of teeth	0	3¼
Wheelbase	4	11

Heating surface, fire box....... 16½ sq. ft. }
Heating surface, tubes......112½ sq. ft. } total, 129 sq. ft

Grate area	4 sq. ft.	
Weight of engine (empty)	5.0	tons.
" water in boiler	0.5	"
" " tank	0.4	"
" coal	0.2	"
" engine in working trim,	6.1	"

The usual load on the incline (exclusive of weight of engine) is 15¾ tons, but on emergency the engine is capable of exerting a tractive force of twice that amount, with a speed of from 10 to 12½ miles per hour.

IRON AND STEEL NOTES.

UTILIZING WASTE BESSEMER METAL.—So much loss and annoyance have been caused through rail ends, old rail bars, and many waste forms of old and new Bessemer steel that makers of Bessemer metal generally will be glad to learn that a cheap and thoroughly practical process has been invented by Mr. W. T. Block, of Hannibal, Mo , for double heating and welding two or more pieces into a homogeneous mass to be wrought into merchantable forms. Any suitable forms of Bessemer steel—such, for example, as rail bars—are reduced to uniform lengths with reference to the purpose to which the finished product is to be applied, and arranged in a convenient form on the bed of the heating furnace, forming a pile without any bands or ties whatever, and consisting of as many pieces as may be desired. Having completed this first stage of the process, which may resemble that in ordinary use in the art, if ties or bands are not used therein, the second stage is commenced, which is the first heating, and which continues until the pile has reached, or nearly reached, the weld heat for this metal, which is the more readily obtained and perfectly distributed where rail bar or similar forms are used in the pile because of the free access of the heat to the inner surfaces of the pile, there being no filling to obstruct free play of the heat or to draw from its intensity.

Care must be taken to prevent any such increase of heat as would be sufficient to burn the steel. The pile is now ready for the second heating prior to the removal to the hammer or rolls. The doors of the heating furnace are opened, thus tempering the heat and a sufficient quantity of iron turnings (those from wrought iron producing the best results) are thrown into it and over the pile and bed of the furnace. The workman then proceeds with the second heating and busselling by rolling

the pile over the turnings on the bed of the furnace, the fagots being now in a sort of temporary weld sufficiently strong in bond to keep together in form. The turnings which the pile gathers up, together with those already thrown over it, weld to the pile, and exert a dual influence. First, they protect it from the increased heat at this stage; and, secondly, they assist in the final welding under the hammer or the rolls. The pile, after having reached the end of the third stage, second heating, is ready to be passed under a hammer or through a train of rolls after the manner that obtains in the ordinary course practiced in the arts. Any ordinary furnace may be used to carry out this process where the degree of heat can readily be regulated and controlled. In handling the pile the instruments common to the trade are employed.—*Mining Journal.*

The Duration of Steel Rails.—Some experiments on the comparative duration of steel rails of different qualities have been recently completed: they were carried out near the Oberhausen station on the Cologne and Minden Railway. After fifteen years' wear it was found necessary to take up the following proportion of different classes of rails.

	Per cent.
Fine-grained iron rails...........	82.
Ordinary iron rails...............	74.
Puddled steel.....................	41 66
Bessemer steel....................	4.71

The iron and puddled steel rails had become useless, chiefly through the tearing and crushing of the head, in consequence of defective manufacture. The following table shows the reduction in the heights of the rails after 15 years' service; the rails were taken from the eastern and western sides of the Oberhausen Station, and the results show an inequality of wear in the two places.

	Reduction in Height.			
	From East Side of Station.		From West Side of Station.	
	mm.	in.	mm.	in.
Fine iron rails from Friedrich Wilhelms-Hütte..............	5.01	1.973	2.94	1.157
Iron rails from the Phœnix Works.....	5.89	2.319	4.05	1.595
Puddled steel from Funcke & Co.......	5.91	2.327	6.06	2.386
Bessemer steel from Hoesch & Co........	7.12	2.803	5.67	2.233
Bessemer steel from F. Krupp..............	6.33	2.492	5.34	2.103
Bessemer steel from Hoerde.............	6.23	2.453	4.90	1.929

To complete this table, the percentage of rails removed should be added; they varied, as above stated, from 4 or 5 per cent. for the Bessemer rails, to 80 per cent. in the iron rails. The few of the latter which remained showed, however, less reduction in height than the steel rails. The mean wear of the Bessemer rails was 6.08 millimeters (3.778 in.) in the fifteen years, and the number of pairs of wheels passing over them was 8,600,000, the wear corresponding to one millimeter (.04 in.) for 6,065,000 tons.

Classification of Steels.—The Société Cockerill, of Seraing, Belgium, arrange their steels into four classes:

1st Class. Extra mild steels. Carbon, 0.05 to 0.20 per cent.; tensile strength, 25 to 32 tons per square inch; extension, 20 to 27 per cent., in eight inches of length. These steels weld, and do not temper. Used for boiler plates, ship-plates, girder-plates, nails, wire, &c.

2d Class. Mild steel. Carbon, 0.20 to 0.35 per cent. Tensile strength, 32 to 38 tons per square inch. Extension, 15 to 20 per cent. Scarcely weldable, and hardens little. Used for railway axles, tires, rails, guns, and other pieces exposed to heavy strains.

3d Class. Hard steel. Carbon, 0.35 to 0.50 per cent. Tensile strength, 38 to 46 tons per square inch. Extension, 15 to 20 per cent. Do not weld, but may be tempered. Used for rails, special tires, springs, guide-bars of steam engines, pieces subject to friction, spindles, hammers, pumpers.

4th Class. Extra hard steel. Carbon, 0.50 to 0.65 per cent. Tensile strength, 46 to 51 tons per square inch. Extension, 5 to 10 per cent. Do not weld, but may be strongly tempered. Used for delicate springs, files, saws, and various cutting tools.—*From Abstracts of Institution of Civil Engineers.*

New Welding Process.—Krupp has recently taken out a German patent for a new process of welding tubes and tires. He draws the tube on a pair of ordinary rolls, and heats the whole length of the portions which are to be welded in a portable fire-box, into which air is blown, so that the heat is directed against the weld. After the necessary heat is obtained, the rolls are set in motion, and the plate which is to be welded is repeatedly drawn through them.

Bessemer Steel Production.—A table has been compiled from semi-official sources, which shows the extent of the production of Bessemer steel in the world. It is stated at 2,170,287 tons for 1877, whilst for last year it had grown to 2,864,605 tons. The increase was the most marked in the cases of the United States, Great Britain, France, and Belgium, in the order named. The production last year was made up in the following proportions: America, 928,972 tons; Great Britain, 834,511 tons; Germany, 460,000 tons; France, 302,516 tons; Belgium, 155,000 tons; Austria, 110,000 tons; Sweden, 19,306 tons; and Russia, 54,000 tons. Great Britain is credited with possessing the largest number of Bessemer converters—104, Germany, Austria, and Sweden, and the United States following. The production of other kinds of steel, especially of steel made by the open-hearth process, is so much larger in Great Britain than in the United States as to make this country still the largest of the steel-producing nations of the world.

STYRIAN CAST STEEL FOR TOOLS.—Messrs. Böhler Brothers and Company, of Vienna, exhibited, recently, two cases containing fractured specimens of tilted ingots of cast steel for tools, remarkable for extreme regularity of structure, the fractures being of a fine silky character in the harder qualities, and uniformly granular in those of a softer kind. They were made at Kapfenberg and Bruckbach in Styria, by the fusion, in crucibles, principally, of blister and refined forge steels, produced from the spathic ore of the Erzberg of Eisenerz. This is the largest known deposit of that substance, and is also celebrated for the extreme purity of the product, which, though containing less manganese than the spathic ore of Siegen, is almost absolutely free from copper and sulphur. Charcoal and vegetable fuel only come in contact with the tool-steel and all the materials it is made of in the smelting processes where the metal is brought into contact with the fuel. The tilting of the bars is entirely done under helve-hammers, driven by water power, except in some of the larger sizes, where steam is used ; but rolling mills are entirely dispensed with. That the hardest, contains tungsten, and has the characteristic almost glassy fracture, due to the presence of that element. Those of a softer character, distinguished as extra hard, medium hard, tough and soft, all contain manganese and silicon in suitable proportion, the latter being derived from the material of the crucible by the action of manganiferous substances added in the fusion.

The following are complete analyses of three qualities :

	Extra Hard. 3.	Between First Quality Hard, and First Quality Medium Hard.	First Quality Tough. 5.
Carbon	1.189	0.943	0.638
Silicon	0.289	0.382	0.383
Phosphorus......	0.023	0.027	0.029
Sulphur..........	0.008	0 011	0.013
Copper	traces	traces	traces
Cobalt and nickel.	"	"	"
Manganese	0.371	0.328	0.446
Trace by diff'r'nce	98.150	98.309	98.491
	100.00	100.00	100.00

RAILWAY NOTES.

RAILWAY ACCIDENTS.—The Board of Trade reports on several accidents have been issued. On the Midland Great Western of Ireland, on the 15th of July, a slight collision occurred at Mullingar Station between a down passenger train from Dublin to Mayo, and an up passsenger train from Sligo to Dublin, when the latter was being backed along the up line to couple with some carriages from Galway. The collision arose through an error of the signalman, who had forgotten to close the points of a crossover road, so that the train backed across the line, and ran into the passenger train from Dublin standing on the down line. On the 24th August a collision occurred on the south side of Motherwell Station (Caledonian Railway) between a portion of a fast goods train from Greenock to Carlisle, and a passenger train from Glasgow to Carlisle; four passengers were shaken. The goods train, consisting of 44 wagons, brake van, and two engines, was stopped by signal on nearing Motherwell Junction, and restarting broke the coupling between the thirtieth and thirty-first wagons, the rear portion thus detached running of its own accord into a branch clear of the main line, and was not missed by the drivers of the train, till the latter was stopped by signals about 1000 yards beyond. Then one of the drivers observing that there were no signal lights at the tail of his train, ran back, and found fourteen wagons missing. He took no pains to protect his train but remained waiting until he saw something approaching, which proved to be the 9.10 P. M. passenger train from Glasgow to Carlisle, which had been allowed to pass by a signalman, although he had received no signal that the line was clear. This accident appears to have been caused by a curious combination of stupidity, and despite the fact that every means to secure safe working were provided. On the 2nd of August, upon the North British Railway, a passenger train from Morningside ran into the tail of a goods train standing partially inside the Haymarket Tunnel, Edinburgh. Fourteen passengers were injured. This accident appears to have been caused by the neglect of the engine driver to notice that the danger signal was against him at the other end of the tunnel. On the same line, upon the 28th of August, a collision occurred at Pennycuick Station. A passenger train standing at the station was run into by its own engine which had been detached and run to the water column. A porter attempted, at the request of the engine driver, to take back the engine, but having started it was unable to stop, so that the engine struck the front end of the train violently, and threw the last carriage into the well of a turntable. Two passengers were injured.

THE ST. GOTHARD TUNNEL.—The International Commission has terminated the inspection of the Saint Gothard line, and according to its estimate, the entire works, so far, have cost 86,609,282 francs, of which 49,991,139 fr. is in connection with the main tunnel, 34,359,143 fr. for the lines by which it is approached, and 2,600,000 fr. for the Mont Cenis tunnel. The work executed in 1879–80 represents a sum of 36,592,360 fr. The subventions were fixed as follows : Italy, 9,523,840 fr. ; Germany, 5,790,436 fr., and Switzerland, 5,751,776 fr.

A LOCOMOTIVE STATION.—An ingenious method, according to *Nature*, for obviating the frequent stoppage of trains at stations, and yet accommodating the passengers from these stations, has been devised by M. Henrez. A "waiting carriage," comprising a steam engine with special gear, and space for passengers and luggage, is placed on a siding at the station, and picked up by the train as it goes past. The latter, by means of a hook on its last carriage, catches a ring supported on a

post, and connected with a cable wound on a drum in the waiting carriage. Thereupon the drum begins to unwind, and in doing so compresses a system of springs, while the carriage is moved at a rate gradually increasing to that of the train. The engine of the carriage then winds in the cable, the train and carriage are connected, passengers are transferred (the carriage being of the American type) from the joined carriage to the train, and *vice versa*, when the two are disconnected, and the engine of the carriage working on the wheels brings it back to the station whence it was taken.

Tramway to the Giant's Causeway.—In the last session a private bill was passed through Parliament, viz.: "The Giant's Causeway, Portrush, and Bush Valley Railway and Tramway Act," which authorizes the construction of road tramways on a system differing from that in ordinary practice, and by which a very great saving in the cost of construction and annual expenditure in working expenses is obtainable. The construction of tramways upon this system, at a cost of about £2,000 a mile, instead of the usual £5,000 to £15,000 per mile, is particularly an advantage to countries like Ireland, or remote districts in England, where tramways constructed at the usual cost could not possibly be remunerative. The proposed new system is suitable rather for road tramways, as distinct from street tramways, for connecting outlying towns, villages, quarries, or mines with the large centers, or railway stations, or for opening up any attractive bits of scenery where a railway would be most objectionable. The tramway is laid on a raised siding along the margin of the road, which forms an ordinary pathway for foot passengers, having a stone kerbing along the outer edge, and graveled or asphalted throughout its length. This siding or pathway is raised about 3 inches to 5 inches above the surface of the road, so as to prevent the passage along it of carts or other vehicles, and so dispenses with the necessity of having to pave the tramway with square sets—a very large item in the usual cost of construction—and also prevents the wear and tear of the surface by other vehicles than the tramcars. The formation width of the tramway is from 6 ft. to 7 ft., on the outside of which the usual country road fence or wall is placed; the gauge of the tramway is 3 ft., laid with ordinary railway rails weighing about 38 lbs. to the yard. On the Giant's Causeway and Portrush Tramway the system above described is to be adopted, and steam traction employed, powers for such having been obtained. It is expected that by this tramway a very large tourist traffic to the Giant's Causeway will be accommodated, in addition to the ordinary local passenger traffic, and a large traffic in goods, iron ore and limestone. The tramway will run alongside the platform of the Belfast and Northern Counties Railway Station at Portrush and be also connected directly with the harbor at Portrush; it will also form a junction at Bushmills with the Bush Valley narrow gauge railway; the tramway is expected to be open for traffic by next summer. Mr. W. A. Traill, C.E., late of H. M. Geological Survey of Ireland, is the engineer.

Indian Railways.—The following statistics are given in the recent report to the Secretary of State for India in Council on Railways in India for the year 1879–80, by Mr. Juland Danvers, Government Director of the Indian Railway Companies:

"The length of the whole railway system of India now open for traffic is 8,611 miles, of which 6,073 miles are in the hands of guaranteed companies, 2,363 miles are State, and 175 are native State lines; 6,693 miles are constructed on the 5 ft. 6 in. gauge, and 1,918 on a narrow gauge. During the past year 395 miles—including the Candahar line—of new railway have been opened for traffic. The railway system is not now terminated by the frontier. A line has been taken from Sukkur on the Indus as far as Sibi, a distance of 133½ miles, in the direction of Candahar. Its further extension to a place about 12 miles from Quetta is now being carried on, but operations beyond this point to Candahar are confined to surveys. On the northwest frontier energetic measures have been taken to continue the Punjab Northern Railway to Peshawur across the Indus at Attock. The bridge, which is in course of construction at this place, will consist of five spans, two of 314 ft., and three of 264 ft. each. It is expected that this line will be so far advanced as to be ready for use up to the left bank of the Indus in November, and from the right bank to Peshawur in January next. Turning to Central India, the remaining link in the railway communication between Delhi and Bombay by way of Ajmere will be finished in the course of the present year. The Rajputana State line will then be opened for traffic throughout. Eighty-two miles of the lower portion between Pahlumpoor and Ahmedabad, where the narrow and the broad gauge systems meet, were opened in November last. The other part of the Rajputana and central Indian system connecting Ajmere with Indore and the Great Indian Peninsula Railway, will probably be opened in the course of 1881. With the exception of a gap of 50 miles, it is expected to be opened on the 1st of January next. The bridge over the Ganges at Benares has been undertaken as part of the system of the Oude and Rohilkund Company, and will be commenced forthwith. It will be the largest work of the kind in India, and is to consist of seven spans of 416 ft., the pier foundations being formed of a solid block of masonry 65 ft. long by 28 ft. wide.

"The net revenue derived from all railways in India during the year 1879 amounted to £5,372,596. That from the guaranteed lines was £5,062,188, compared with £5,002,028 of the previous year. The guaranteed interest paid by the Government was covered, leaving a balance in favor of revenue of £313,955. The net receipts of the State lines amounted to £310,408, compared with £200,374 of the year 1878. The gross receipts of the guaranteed lines were £9,765,284, and the expenses £4,703,096. On the State lines the gross receipts were £1,465,824, and the expenses

£1,155,416, showing an average proportion of net receipts to expenditure on the guaranteed lines of 51, and on the State lines of 22 per cent. In making these comparisons, he says, it must be observed that the State railways are for the most part either political lines recently opened, or small branches with little traffic on them and expensive to work, but serviceable as feeders to the main lines. The Rajputana line, running south from Agra and Delhi, may be regarded as an exception to this description. The total net earnings divided over the total capital outlay, both guaranteed and State, yielded a return at the rate of £4 7s. per cent. per annum. The guaranteed lines earned at the rate ot £5 4s. per cent. per annum.

"The capital expended on the Indian railways up to the end of the official year was £123,124,514. Of this £97,327,851 had been expended on guaranteed lines, £24,403,797 on State lines, and £1,392,866 on lines in native States. The capital expenditure during the period covered by this report—fourteen months in the case of the State railways, nine months in that of the East Indian Railway, and twelve months in that of the other guaranteed lines—was £5,388,772, being £883,185 on guaranteed and £4,505,587 on State lines.

"The number of passengers increased from 38,489,586 in the year 1878 to 43,144,468 last year. The proportion per cent. of first-class was .519, of second, 2.049, and of the lowest classes, 97.432.

"The aggregate quantity of goods carried on all lines amounted to 7,876,766 tons as compared with 7,296,335 of the previous year. The amount received for the conveyance of the same was £7,248,752, compared with £6,734,059 in 1878. The chief articles carried were cotton, grain, rice, piece goods, military stores, salt, seeds, tobacco and opium.

"The expenses of working and maintenance during the year amounted to £5,774.510, compared with £5,101,335 of the previous year. The cost of maintenance was £1,463,550, and of working £4,310,960.

"The rolling stock employed in working the railways consisted of 1,850 locomotives, 4,294 passenger carriages, and 34 856 trucks. The total train mileage during the year was 28,915,144, compared with 26,570,395 of 1878. The passenger train mileage was 5,392,544, the goods 13,546,878, the minerals 357,561, and the mixed goods and passengers 8,964 032.

"The goods shipped to India from this country for the use of the railways amounted during the year to 207,743 tons, of the value of £1,578,404, the freight and insurance of which was £315,181. Besides this, 143,279 tons of coal, 1,938 chaldrons of coke, and 8,393 tons of patent fuel were sent out."

ORDNANCE AND NAVAL.

The New Field Gun.—The trials made with the new 13-pounder breech-loader at Okehampton Park have been brought to a conclusion. The only defect in the gun is the tendency of the lever handle of the breech to spring up at the shock of the discharge—a defect which very nearly caused a catastrophe last week by the breech-piece of the gun being sent flying to the rear. A new method of securing the breech will probably be considered. In respect of speed the accuracy of firing the gun greatly surpasses those now in use.

BOOK NOTICES.

Publications Received.

Occasional Papers of the Royal Engineer Institute.

Le Genie Civil, Tome I, No. 1.

Annual Report of the Chief of Engineers of the United States Army, 1880.

The Textile Manufacturer, Oct. 1880.

Modern Architectural Designs and Details.—Part I. New York: Burnell & Comstock.

This advance number of a series of ten parts which, when completed, will be a liberal sized quarto, is full of promise.

Each part is to contain eight lithographed plates. The present number contains:

Plate 1. Per-pective and Plans of a Queen Anne Cottage.
" 2. Three Elevations of Same.
" 3. Framing Plans Showing Construction.
" 4 and 5. Exterior Details of Same.
" 6. Interior " "
" 7. Porch and Details.
" 8. Four Piazzas and Details.

All elevations and details are drawn to scale.

The future numbers will contain designs for dwellings, stores, offices, etc. The large number of contributors will ensure diversity of style.

Steam Boilers: Their Design, Construction and Management. By Wm. H. Shock, Engineer-in-Chief U. S. Navy; Chief of Bureau of Steam Engineering, U. S. Navy. New York: D. Van Nostrand.

This long-needed work appears at length in a style and of dimensions commensurate with the importance of the subject. A handsome quarto of 470 pages of text, 36 full page plates, and 148 interspersed wood cuts, is devoted entirely to steam boilers.

The author wastes no space on general discussions or historical sketches. In briefest possible way mention is made of the fact, that in early times cast iron, and in exceptional cases, granite and wood were used in boiler construction, then copper was in favor till 1858, then plate iron was used, and now steel seems likely to become the favorite material, with improved methods of construction. So much is disposed of in exactly one page of the book. The author then introduces the subjects as follows:

"The essential parts of a steam boiler are:

1st. The ashpit or chamber beneath the grate.

2nd. The grate lying between and separating the ashpit from the furnace.

3rd. The furnace or chamber above the grate.

4th. The flues or tubes and their connecting chambers, extending from the furnace to the chimney.

5th. The chimney.

6th. The water-room enclosing the furnace, tubes, flues, and connecting chambers.

7th. The steam-room lying above the water-room."

After explaining very briefly the interdependence of these parts, the author adds:

"It is quite evident that an ingenious engineer could form of the elementary parts of a boiler just enumerated an almost infinite number of combinations; those which have actually been devised and executed are so numerous that a large space would be required to describe them, and their description, for the most part, would be as useless as tedious, as they are to be found extensively illustrated in patent office reports and in existing engineering literature, the present essay will be restricted to a consideration of only such as have been found, by long experience, to meet the requirements of practice, and chiefly of those best adapted for use on board of war and ocean merchant steamers."

The topics treated by chapters are:

I. Introductory; II. Combustion; III. Transmission of Heat and Evaporation; IV. Materials; V. Testing the Materials; VI. Strength of Boilers; VII. Designs, Drawings and Specifiations; VIII. Laying off, Flanging, Riveting, Welding, etc., IX. Shell, Furnaces and Back Connections; X. Stays and Braces; XI. Flues and Tubes; XII. Uptake, Chimney, Steam Jets, Fan Blowers, etc.; XIII. Steam Room and Superheaters; XIV. Setting and Erection of Boilers; XV. Boiler Mountings and Attachments; XVI. Tests, Inspections and Trials of Steam Boilers; XVII. Management of Boilers; XVIII Causes and Prevention of Deterioration of Boilers; XIX. Boiler Explosions.

WAS MAN CREATED? By HENRY A. MOTT, JR., E. M., Ph.D. New York: Griswold & Co.

This work presents in a direct and concise way the belief of the modern evolutionist, and sets forth the phenomena upon which the belief is founded. To quote the author's preface:

"This work is written for the man of culture who is seeking for truth—believing as does the author, that all truth is God's truth, and therefore it becomes the duty of every scientific man to accept it; knowing, however, that it will surely modify the popular creeds and methods of interpretation, its final result can only be to the glory of God and to the establishment of a more exalted and purer religion."

The illustrations, of which there are many of fair quality, are offered, for the most part, to show that the differences in structure between consecutive units in a carefully selected series in the animal kingdom, are no greater than may be reasonably supposed to have arisen from a natural development. So, from the monera and ameba to man, many illustrations are presented to show the character of the differences between the successive steps in the line, or rather lines, of development. Well selected illustrations also exhibit the changes during the growth of mammals from the fœtal stage to the adult individual.

The work is a good one for the library, exhibiting as it does a chain of argument which is satisfactory to modern naturalists, and which seems to gain strength from every new discovery in natural history.

OBITUARY.

Mr. William Minifie, a well known author, died in October at his residence in Baltimore. He was an architect and the author of four important works—one a text book of geometrical drawing, perspective and shadows, with plates; another, a royal octavo text book of mechanical drawing, highly recommended by the London *Art Journal* and the New York *Scientific American;* another, an essay on the theory and application of color; and the fourth, a series of lectures on drawing and design. The octavo edition was introduced into the Department of Art of the British Government at Marlborough House in 1853, and by the authority of the Lords of the Committee of Privy Council for Trade, it was placed in the list of publications recommended to the schools of art and design throughout the kingdom. Up to this date fifteen editions have been published

Mr. Minifie was born in Devonshire, England, in 1805, and emigrated to Baltimore about fifty years ago. His early efforts were as a shipjoiner and carpenter. In September, 1845, he was elected teacher of drawing in the Central High School of Baltimore, a position he occupied five years. Drawing had not previously been taught in the public schools of the city. The course of instruction adopted was very similar to the Smith system now used in our schools. In 1837 he designed and built the Front Street Theater, which was generally considered at the time equal, if not superior, to any theater then existing in the United States. It was much praised by prominent actors and others for seeing, and for its acoustic qualities.

In 1836 he was elected a member of the Maryland Academy of Science and Literature of Baltimore. This association was dissolved in 1844 for want of support, and Mr. Minifie, as curator, attended to the distribution of its effects. He was one of the original members of the present Maryland Academy of Sciences, and was also a member of Baltimore Chapter of the American Institute of Architects and of the Decorative Art Society. In 1858 he was elected a member of the American Association for the Advancement of Science, but in consequence of increased deafness he has not taken an active part very lately in any of the associations. He was a public-spirited man and interested in all public improvements.